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Sediment transporting flows in headwater streams: a report to the Intermountain Research Station, US Forest Service

Peter J. Whiting, et al.

FINAL REPORT FOR RESEARCH AGREEMENT
#INT-93818-RJVA
"Channel Forming Flows in Headwater Streams"
CASE WESTERN RESERVE UNIVERSITY
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Sediment transporting flows in headwater streams

A report to the Intermountain Research Station, US Forest Service

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July 15, 1997

Executive Summary

The general objective of this study was to study the range of streamflows that are important in forming and/or maintaining channel form and function in headwater streams in the snowmelt-dominated region of the Intermountain West. Headwater streams are defined herein as those streams with the majority of their drainage at elevations above 1200 m (4,000 feet) and having drainage areas less than 400 km^2 (150 $mile^2$). The twenty-three streams studied are in central and northern Idaho and all streams are within the Columbia River Basin. Gradients of the studied reaches range from 0.0043 to 0.067. Grainsize varies from 4 to 207 mm. Diversions of flow and basin disturbance have been minor in most of these drainages.

Bedload was measured for 2 to 10 or more years at sites by standard methods. Flow records used in analysis had lengths of 15-84 years. We developed a technique based upon Hirsch (1982) for extending short period records by correlation to a longer record. Longitudinal and cross-sectional surveys, maps, and pebble counts were made for all sites. Painted rocks and subsurface grain size studies were made at select sites.

Bedload is finer than surface and subsurface particles suggesting selective transport of the finer sizes. Although much of the load is sand, painted rock experiments demonstrate that particles up to the D_{90} were moved during the 1995 snowmelt which was above bankfull at sites. Clockwise hysteresis in bedload was demonstrated at a select group of sites. Surface armouring and hysteresis are consistent with supply limitations in these streams.

The percent of bedload moved by flows below mean annual discharge averages 6 percent in the 23 streams. Almost one-half the water is used to move the first 10 percent of the bedload. The percent of bedload moved by flows above the bankfull discharge averages 37 percent. The bedload effective discharge has a recurrence interval that averages 1.5 years and the magnitude of the effective discharge is slightly less on average than the bankfull discharge. The recurrence interval of bankfull discharge averages 2.1 years. The magnitude and frequency of effective discharge and frequency of bankfull discharge are very similar to that found in other studies of lowland gravel-bed rivers.

Introduction

It is said that alluvial streams are the architects of their own geometry (Leopold, 1994). This is undoubtedly true, and means that the channel has created an equilibrium form that allows it to pass the water and sediment supplied to it from upstream given the constraints of climate, topography and geology. A key to understanding the creation of the equilibrium channel characteristics, or the maintenance of these characteristics, is to be able to relate the sediment moved to the magnitude and frequency of flows of water.

A stream carries a range of sediment sizes - sizes that are moving as washload, suspended load, and/or bedload. The sediment that is most relevant to the creation or maintenance of the channel geometry is that material that is making up the bed and banks. In upland channels, the coarse nature of the load means that much of the material moves through the channel as bedload. The bed and banks are composed of this coarse material hence the channel geometry is related to the magnitude and frequency of flows transporting bedload. In more lowland, gentle gradient channels, the load is typically finer and a larger portion of it is moved in suspension as compared to as bedload. The channel bed and particularly the banks are often composed of both materials. For these channels, the channel geometry may be related to the magnitude of flows transporting suspended load and/or the finer bedload.

Most studies of the amount of sediment moved by different flows, especially as they relate to channel geometry, have focused on lowland rivers (Wolman and Miller, 1960) or on the suspended component of the load (e.g. Andrews, 1980; Ashmore and Day, 1988; Nash, 1994). Most of these studies, but not all, have indicated that the most sediment is transported by flows that are near bankfull (Wolman and Miller, 1960; Andrews, 1980; Andrews and Nankervis, 1995) and have a recurrence interval of about 1.5 years. Large flows move more sediment on a day-by-day basis but occur less frequently than the flows that just fill the channel, such that in total, the bankfull discharge is thought to be the most effective discharge in transporting sediment, and by extension, most important in maintaining channel form and function.

Headwater streams, as mentioned earlier, are typically coarser and steeper than lowland channels and transport much of their load as bedload. Despite these differences the assumption has held that smaller headwater channels behave in a manner similar to larger lowland streams. There is some limited support for such a view. Emmett (1975) found that a variety of streams draining to the Salmon River in Idaho had a bankfull flows that had a recurrence interval of near 1.5 years; a frequency equivalent to effective discharge in lowland streams. Carling (1988) and Pickup and Warner (1976) found that the effective event in small basins was about that reported for larger basins. There is no essential difference in the relationship between effective discharge and bankfull discharge for small and large basins in the data of Andrews and Nankervis (1995). Nash (1994)

found no relation between effective discharge and basin size. On the other hand, there is ample evidence that more-extreme, less-frequent events play a more important role in smaller basins than in larger basins (Costa, 1974; Grant et al, 1990). Ashmore and Day (1988) found that the effective discharge for suspended sediment was a rarer and more extreme event in smaller drainage basins. Pitlick (1988) found that the effective discharge for predicted bedload at seven gaging stations in northern California became an increasingly rare event as the gradient and bed material size increased. For slopes less that 1% the recurrence interval was less than 2 years whereas at a slope of 2% the effective discharge had a recurrence interval of exceeding 75 years.

The general objective of this study was to study the range of streamflows that are important in forming and/or maintaining channel form and function in headwater streams in the snowmelt-dominated region of the Intermountain West. For the purpose of this study, headwater streams are defined as those streams with the majority of their drainage at elevations above 1200 m (4,000 feet) and having drainage areas less than 400 km^2 (150 $mile^2$). The twenty-three streams studied are in the Northern Rocky Mountain Physiographic province (Fenneman, 1931) in Idaho (Figure 1). All streams are within the Columbia River Basin, and with the exception of Catspur Creek in northern Idaho, all are tributaries of the Salmon River or Clearwater River.

The rest of this report describes the field sites, methods employed and analysis completed as part of this study.

Field sites and methods

Description of Study Sites

The selection of suitable channel reaches for a detailed study of the importance of various flows in transporting sediment in headwater streams was completed in 1993. During field reconnaissance in October 1993, we evaluated a variety of prospective sites in central Idaho. The criteria for selection was that the channel met our definition of headwater streams, was relatively undisturbed, had a gage or was near a stream with a gage, was accessible relatively early in the spring, and was near other sites selected for study. We selected a total of six channels for detailed study by our personnel during 1994 and 1995 water years. These sites were Thompson Creek, Squaw Creek and Herd Creek near Clayton, Idaho, and Valley Creek near Stanley, Idaho, Marsh Creek northwest of Stanley, and Fourth of July Creek south of Stanley. See Table 1 below for information on sites and Figure 1 for locations of sites.

Table 1- Primary study sites

Site	Drainage Area, km^2 ($miles^2$)	Elevation, m (feet)	USGS gage (Y or N)	Years of operation
Fourth of July Creek	44.2 (17.1)	2190 (7200)	N	1994 - 95
Herd Creek	308 (119)	1790 (5880)	N	1994 - 95
Marsh Creek	196 (75.7)	1990 (6540)	N	1994 - 95
Squaw Creek	205 (79.0)	1740 (5710)	Y	1971-
Thompson Creek	56.4 (21.8)	1830 (6000)	Y	1973-
Valley Creek	381 (147)	1900 (6220)	Y	1921-72, 1992-

At Thompson Creek we worked above the confluence of Pat Hughes Creek, 4.3 km (2.7 miles) above the existing US Geological Survey (USGS) gage. At Squaw Creek we worked just downstream from the existing USGS gage including land leased by the Thompson Mining Company. At Herd Creek we worked 2.6 km (1.6 miles) upstream from the confluence with the East Fork of the Salmon River. The site is below the Bennett Ranch on land administered by the Bureau of Land Management. At Valley Creek we worked within sight of the USGS gaging station at the town of Stanley. Most measurements were made from an existing wooden footbridge, but the largest flows were measured in a wider part of the channel downstream of the gage. At Marsh Creek we worked below the US Forest Service road bridge over Marsh Creek, just below the confluence of Marsh Creek and Cape Horn Creek. The USGS operated a gage for the period 1928-72 1.6 km (1.0 mile) downstream. During high flows we measured flow and sediment transport in a locally wider reach 80 m downstream of the bridge. At Fourth of July Creek we worked a reach of channel that is 4.6 km (2.9 miles) east of Highway 75. This site is upstream of the stage plate on Fourth of July Creek that is read intermittently by USFS personnel.

In addition to the six primary study sites, we identified ten streams in other parts of Idaho that are monitored to varying degrees by USFS personnel (Table 2) and met our criteria of headwater streams. At these sites, gages are operated for at least the period of break-up to freeze-up and discharge and sediment transport measurements (bedload and suspended load) have been made by the US Forest Service for several years. These sites include Blackmare Creek near Poverty Flats, Little Buckhorn Creek and West Fork Buckhorn Creek near Krassel, Dollar Creek near Warm Lake, Hawley Creek near Leadore, Johns Creek near Grangeville, Main Fork Red River near Elk City, South Fork Red River near Elk City, Squaw Creek near Salmon, and Trapper Creek near Elk City. One site, Jesse Creek near Salmon, was dropped from the study because of insufficient bedload data. Seven other sites were studied for a related project - Canyon Creek near Lowell, Catspur Creek near Bovill, Eggers Creek north of Garden Valley, Fish Creek near Lowell, Little Slate Creek north of Lucille, Lolo Creek northeast of Kamiah and Rapid River near Riggins. While these sites were not included initially because the lower elevation of the gages suggested the hydrographs might not be dominated solely by snowmelt, the results are useful for this study and

are included. Moreover, even these watersheds with low elevation gages have the vast majority of their drainage area at elevations above 4000 feet where snowmelt is the dominant hydrologic event of the year. We are calling sites where we did not collect the flow and transport information ourselves, secondary sites. Figure 1 shows locations of sites.

Table 2 - Secondary sites

Site	Drainage Area km^2 ($miles^2$)	Elevation of gage, m (feet)	Years of Operation	Data collector
Blackmare Creek	46.1 (17.8)	1270 (4180)	1990-94	USGS/ USFS
Canyon Creek	49.7 (19.2)	550 (1800)	1992 -	Clearwater NF
Catspur Creek	28.0 (10.8)	890 (2930)	1987 -	Panhandle NF
Dollar Creek	16.8 (6.50)	1490 (4900)	1990-94	USGS/ USFS
Eggers Creek	1.29 (0.50)	1450 (4750)	1975-84	USFS
Fish Creek	225 (87.0)	600 (1980)	1975 -	Clearwater NF
Hawley Creek	109 (42.2)	2040 (6700)	1989 -	Salmon NF
Johns Creek	293 (113)	730 (2400)	1978 -	Nez Perce NF
Little Buckhorn Ck	15.5 (5.99)	1220 (4010)	1990-94	USGS/ USFS
Little Slate Creek	162 (62.6)	1070 (3510)	1978 -	Nez Perce NF
Lolo Creek	106 (41.0)	930 (3040)	1982 -	Clearwater NF
Rapid River	190 (73.3)	670 (2200)	1986 -	Nez Perce NF
Red River	129 (49.7)	1310 (4300)	1985 -	Nez Perce NF
SF Red River	98.9 (38.2)	1310 (4300)	1980 -	Nez Perce NF
Squaw Creek	37.0 (14.3)	1200 (3950)	1989 -	Salmon NF
Trapper Creek	20.7 (8.00)	1510 (4950)	1976 -	Nez Perce NF
WF Buckhorn Ck	58.5 (22.6)	1200 (3950)	1990-94	USGS/ USFS

NF - abbreviation for National Forest

The flow records for Marsh Creek, Thompson Creek, Squaw Creek and all secondary sites are unaffected by any diversions. There is some diversion of water upstream of the study site on Herd Creek. Water is applied to the small steep pastures along Herd Creek and runs back into the stream with minor losses (D. Baker, pers. comm.). Valley Creek above the gage has numerous small and large diversions but most of the diverted flow returns to the channel after coming off the fields (M. Moulton, pers. comm.). A portion of the flow on Fourth of July Creek is diverted upstream of the study site. The diverted water does not return to the channel and is lost to the system. The diversion appears to be less than 0.1 cumecs and during 1994 occurred from July 7 to September 20 and in 1995 from August 25 to September 25; the diversion does not appear to affect peak flows.

The geology of the drainages containing the study sites is varied. Bedrock geology includes the Idaho Batholith, volcanics, and metasediments (Maley, 1987). At least one site was glaciated - 4th of July Creek (Williams, 1961). Bedrock is exposed locally in the bed and/or banks of several streams - Canyon Creek, Fish Creek, Herd Creek, Johns Creek, Little Slate Creek, Lolo

Creek, Rapid River, Squaw Creek near Clayton and Thompson Creek. Nonetheless all sites have substantial alluvial cover that allows for the development of a self-formed channel. The channel reaches studied include A, B, and C type channels (Rosgen, 1994) and the channel architecture includes riffle pools, planar beds and step-pools (Montgomery and Buffington, 1993). Vegetation around the channels ranges from sage and grass, willows, to conifer forest. Precipitation in the basins is as low as 25 cm to as high as 180 cm (University of Idaho, 1995). All streams are within the Columbia River Basin and, with the exception of Catspur Creek in northern Idaho, all are tributaries of the Salmon River or Clearwater River.

Field Methods at Primary Sites

Field measurements at the six primary sites were made in 1994 and 1995. In 1994, the research team regularly made measurements of flow and sediment transport (bedload and suspended load) from April 26 to June 15. In 1994, the field crew consisted of one post-doctoral researcher who supervised four graduate and undergraduate students. In 1995, the field measurements at the six primary sites began April 22 and continued regularly to July 5. Some limited discharge and sediment sampling occurred after early July. In 1995, the field crew consisted of one post-doctoral researcher and four graduate and undergraduate students.

Stage determination

At all sites, a stage plate was installed or the existing stage plate was located and surveyed. At the three primary sites without an operating USGS gage, a pressure transducer was installed to monitor continuously the stage[1]. This system relies on a Telog® pressure transducer that measures hydrostatic pressure every 5 sec and then stores the average value during 10 minute intervals. The hydrostatic pressure is then converted to stage. The pressure transducers monitored stage from mid-April to late October in both years. Stream ice-up prevents stage measurement during winter using our methods.

Flow measurement

Flow velocity was measured with Price and Pygmy current meters attached to a topset wading rod. At very high flows at Marsh Creek, Valley Creek, and sometimes at Squaw Creek, discharge was measured from a bridge and the current meter was attached to a hand-held metal extension rod of our own construction. The flow meter was positioned at 0.6 the depth and the point velocity taken as the mean velocity in the column of water. Each revolution of the cup on the meter was counted on a digital recorder and the total number of counts converted to flow velocity. Velocity was measured for 70 seconds at typically 20 to 26 equally spaced points across the

[1] Herd Creek, Marsh Creek and Fourth of July Creek.

channel. The velocity measurements and local depth measurements were integrated across the channel to give the flow discharge -- the mid-section method used by the US Geological Survey and shown by Hipolito and Loureiro (1988) to give the most precise measurements of total discharge through a section.

Rating curves specifying the relationship between stage and water discharge were built for each primary site. At primary sites where a USGS gage was in operation, we compared our rating curve to the USGS rating table for the station and found good correspondence between the two stage-discharge relations.

Flow records

Hydrographs were built from the record of stage height and the rating curve specifying the discharge associated with stage. For Thompson Creek, Squaw Creek and Valley Creek, the flow information was provided by the USGS. For Fourth of July Creek, Herd Creek and Marsh Creek, we generated the hydrograph in 1994 and 1995 from the pressure transducer record converted to stage and in turn converted to flow discharge.

Bedload measurement

Bedload was measured by the single equal width increment (SEWI) method in accordance with suggested methodologies (Edwards and Glysson, 1988). A hand-held 3 inch (7.6 cm) Helley-Smith sampler with a 0.25 mm mesh was placed on the bed for a uniform period (30 or 60 seconds) at 20-25 equally spaced intervals across the channel. On a handfull of dates less than 20 verticals were made. Two traverses (occasionally three) to collect bedload were made and sediment from each traverse was bagged, labeled and sent to Case Western Reserve University for drying, weighing and grainsize analysis. Sediment was sieved into 0.5 phi intervals. The intermediate axis (b-axis) of the coarsest particle in each sample was measured with a caliper and the size recorded.

Suspended load measurements

Suspended load was measured with depth-integrating samplers using the equal discharge increment (EDI) method (Edwards and Glysson, 1988). Typically five water samples were taken. Samples were stored in the dark until suspended load concentration was determined by the sediment laboratory at the Helena National Forest (by Bo Stewart). Concentrations were established to 0.01 mg/L for the fractions coarser and finer than 0.063 mm. Most bedload and suspended load samples were taken while personnel waded, but at high flows at Marsh Creek, Valley Creek, and occasionally at Squaw Creek, measurements were made from a bridge and the sampler was attached to a metal extension rod.

Painted rock experiments

Two transects containing painted rocks were established at all the primary sites except Marsh Creek. Particles ranging in size from about D_{25} to D_{90} were dried and painted. At twenty equally-spaced points across the channel one of the painted rocks was placed on the bed in a pocket between grains with the shortest axis (c-axis) pointing upward. The particle that was placed was chosen randomly from the pool of previous painted grains. The distance across the channel where the painted rock was placed as well as the length of the three principle particle dimensions were recorded. Movement of any of the grains was noted during site visits when the flow was clear enough to permit observation of the bed. After the spring snowmelt, the total downstream displacement of grains was measured. Particles were removed from the bed for measurement only after the snowmelt.

Site surveys

Each of the primary study sites was intensively surveyed and described. Maps over a reach of typically 20 or more channel widths were made to show major planform features and the locations of cross-sections and gages. At one channel width intervals, the water surface along each bank on the day of the survey and the channel bed at the channel centerline were surveyed. The elevation of bankfull along the channel as previously flagged by Peter Whiting during his earlier visit to the sites (with Bill Emmett) was surveyed as well. Bankfull was defined following Emmett as the relatively flat, frequently inundated surface adjacent to the channel built by the channel in its current hydrologic regime (Bill Emmett, pers. comm.). Bankfull was surveyed only where there was a distinct morphologic feature corresponding to the floodplain. Surrogates for bankfull such as vegetation, sediment size or stain lines were not surveyed although they were at times somewhat useful in confirming subtle bankfull features. Care was taken to avoid nearbank slumps. The number of bankfull points surveyed at the primary sites site ranged from 13 to 31. Rarely were surveyed points within 5 meters of another point. In 1995, the water level at a stage near bankfull was surveyed along each bank in the vicinity of the gage. Approximately four (and as many as six) cross-sections showing the channel and valley features were established and permanently marked. These surveys were tied to the datum of the gage (and other benchmarks) in order to be able to link gage height and discharge to various levels of channel flow and floodplain inundation. In the course of the measurement of the topography, grain sizes on the channel bed and vegetation and soil properties of the valley bottom were described. Cross-sections extended at least 5 meters beyond the level of bankfull or at least 1 m above bankfull on steep slopes.

Surface pebble counts

Surface pebble counts at a representative reach or in representative reaches were made at each site (Wolman, 1954). Particles were selected for measurement of their intermediate axis (b-

axis) at approximately equal-spaced intervals along 4 or 5 transects across the bankfull width of the channel. The exact particle measured at each equal increment was chosen blindly. A minimum of 100 particles (but often more) were measured for each pebble count - the exact number depended upon the number of transects and transect width. In every case a transect was completed once it was begun.

Field Methods at Secondary Sites

At secondary sites, we relied upon the existing USFS information on flow and sediment transport, but we made our own site surveys and surface particle size determinations.

Methods used for recording stage and measuring flow and sediment discharge at the secondary sites monitored by US Forest Service personnel were generally similar to those employed by us at the primary sites. Current meters, bedload samplers and suspended load samplers were of the same type. At some USFS sites, measurement of flow and sediment transport was done from cableways at high flows. Stage recorders differed from our pressure transducers - some Forests used paper traces while others used digital recording. Flow records at USFS sites were generated using the program HYDRA (USFS ref). At some USFS sites, particularly when they were first established, measurements of flow and sediment transport were less frequent than the 20-25 measurements that has been typical in recent years. In our analysis, we disregarded flow or bedload measurements taken for less than 30 s or at less that 10 points across the channel. Bedload collected in 1994 and 1995 was sieved at 1-ϕ intervals while in previous years size analysis was typically for fisheries use and particles were sieved into about four fractions.

The surveying protocol used by our personnel at secondary sites was identical to that used at the primary sites. US Forest Service personnel flagged high water in 1995 along each bank at select sites[2] and these elevations were surveyed later by our personnel.

Subsurface grain size analysis

Subsurface particle size measurements were made at select secondary sites by US Forest Service personnel. A 55-gallon drum cut in half and with its end removed was placed on the bed. Surface grains were removed and then the material below the surface was sampled. The principal dimensions of grains coarser than 63 mm were measured, while grains between 16 mm and 63 mm were wet-sieved in the field and grains finer than 16 mm were sieved in the laboratory. Surface particle size measurements were also made by USFS personnel in conjunction with subsurface measurements.

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[2]Johns Creek, Little Slate Creek, Lolo Creek, Rapid River, Red River, South Fork Red River, and Trapper Creek

Results

The headwater channels investigated span a large range of geometry and particle size (Table 3). Stream gradients of the reaches range from 0.0043 - 0.0670. The method used to determine the gradient requires that the equations for the bankfull level, the water surface during the survey period, and the channel bed at the centerline have identical slopes, but allows distinct y- intercepts. The value reported herein is that common slope. Stream gradient decreases as drainage area increases (Figure 2). All channels have a gravel bed: surface particle size ranges from 4 to 207 mm (Table 3). Surface particle size is generally larger in larger basins (Figure 3). Bankfull width (W_B, in m s^{-1}) and bankfull depth (D_B, in m) increase with drainage area (DA, in km^2) (Figure 4; Table 3). The equations for bankfull width and depth are:

$$W_B = 1.398\ DA^{0.452} \quad r^2 = 0.716$$
$$D_B = 0.116\ DA^{0.304} \quad r^2 = 0.629$$

The streams are A, B, and C type channels (Rosgen, 1994) and the channel architecture includes riffle-pools, planar beds and step-pools (Montgomery and Buffington, 1993) (Table 3). Appendix A collects all maps, cross-sections, longitudinal profiles and surface particle analyses of primary and secondary sites.

Bankfull discharge (Q_B) increases with drainage area (Figure 5 and Table 3). Bankfull discharge was determined for sites from the stage reading associated with intersection with the stage plate of the equation describing the longitudinal elevation of bankfull level. The bankfull discharge is determined from the stage-discharge curve for the gage. For a few sites, projection of the bankfull elevation to the gage produced unlikely results because of local hydraulics near the gage. In these cases, the difference between the surveyed high water and the bankfull were used to estimate bankfull stage. The increase in bankfull discharge is nearly linear (exponent equals 0.958) with drainage area. This power fit was chosen over a linear regression to represent the data because of the way it handled small drainage basins and because of the manner it handled other data for larger basins (W.W. Emmett, unreported data, 1996). There is large scatter about the line; several of the low bankfull discharge values - the three lowest values above 100 km^2 (Hawley Creek, Squaw Creek near Clayton, and Herd Creek) - are in relatively drier basins. The large bankfull discharge value near 50 m^3/s at Johns Creek may represent an overestimate of the bankfull elevation, thus discharge.

Table 3 - Characteristics of primary and secondary sites

Stream	Slope	D50 (mm)	Rosgen Stream type	Channel architecture	Bankfull Q (m^3/s)	Width (m)	Depth (m)
Blackmare Cr	0.0299	95	B3	planar	4.73	10.77	0.42
Canyon Cr	0.0486	140	B3a	step-pool	6.48	10.71	0.43
Catspur Cr	0.0105	27	C4	riffle-pool	2.36	4.91	0.35
Dollar Cr	0.0146	74	3Bc	planar	6.43	8.85	0.44
Eggers Cr	0.0670	4	B4a	planar	0.0478	1.44	0.10
Fish Cr	0.0280	140	A3b	planar	20.9	18.83	0.80
4 July Cr	0.0202	51	B4c	planar	3.88	6.65	0.39
Hawley Cr	0.0183	40	B4	planar	1.33	6.73	0.28
Herd Cr	0.0077	67	C3	planar	5.46	8.15	0.49
Johns Cr	0.0207	180	B3	planar	49.0	19.49	1.12
Little Buckhorn Cr	0.0509	28	A4	step-pool	- - [1]	- -	- -
Little Slate Cr	0.0254	207	B3	planar	13.0	15.19	0.46
Lolo Cr	0.0091	90	B3c	planar	11.7	16.75	0.62
Marsh Cr	0.0059	57	C4	planar	20.8	19.04	0.6
Rapid River	0.0128	94	B3c	planar	17.7	24.33	0.54
Red River	0.0060	68	C3	riffle-pool	9.34	11.54	0.54
SF Red River	0.0142	86	C3 / B3c	planar	7.25	10.88	0.44
Squaw Cr (USFS)	0.0246	27	B4	planar	0.623	3.53	0.24
Squaw Cr (USGS)	0.0100	43	C4	step-pool	5.12	11.02	0.39
Thompson Cr	0.0153	66	C4b	planar	2.48	6.87	0.24
Trapper Cr	0.0410	67	B3a	step-pool	2.56	6.43	0.36
Valley Cr	0.0043	49	C4	planar	28.6	32.00	0.76
WF Buckhorn Cr	0.0320	180	B3	planar	5.72	9.35	0.55

[1] Bankfull could not be identified at this site.

Hydraulic geometry for bankfull discharge (Q_b, in $m^3\ s^{-1}$) for the sites can be described by the following equations:

$$W_B = 4.683Q_B^{0.447} \quad r^2 = 0.914$$
$$D_B = 0.254Q_B^{0.320} \quad r^2 = 0.922$$
$$V_B = 0.896Q_B^{0.217} \quad r^2 = 0.705$$

Figure 6 shows the hydraulic geometry as a function of bankfull discharge. In comparison, Emmett (1975) found the following relations in his study of tributaries of the Salmon River in central Idaho:

$$W_B = 2.86Q_B^{0.54} \quad r^2 = 0.917$$
$$D_B = 0.26Q_B^{0.34} \quad r^2 = 0.887$$
$$V_B = 1.35Q_B^{0.12} \quad r^2 = 0.486$$

Please note that the coefficients have been modified from how they appear in Emmett (1975) to account for unit conversions. When the analysis herein is limited to the range of bankfull discharge spanned by Emmett (1975), the coefficients and exponents are more similar:

$$W_B = 4.305Q_B^{0.487} \quad r^2 = 0.870$$
$$D_B = 0.246Q_B^{0.336} \quad r^2 = 0.867$$
$$V_B = 0.981Q_B^{0.174} \quad r^2 = 0.453$$

Hydrology of sites

These upland channels reach peak flows in April, May or June in association with spring snowmelt. Some of the northern basins, particularly those at lower elevation experience occasional high flows during fall and winter associated with cyclonic storms and with rain-on-snow events. In most channels, fall and winter are times of very low flow.

Water year 1994 (October 1, 1993 - September 30, 1994) was unusually dry (US Geological Survey, 1994). October-March precipitation averaged 60 percent of normal (Natural Resources Conservation Service, 1994). April had normal to above normal temperatures and precipitation and most low elevation snow melted by the end of the month. The paltry snowpack and a warm spring contributed to discharges at most sites that approached only about 70 percent of bankfull and runoff which peaked early in the season. The peak discharges in 1994 at sites correspond on average to 1.5 year recurrence interval flows.

Water year 1995 was far wetter, particularly in southern and central Idaho (US Geological Survey, 1995). An early snowpack was built in November and was followed by heavy snows in December. Heavy rains on low-elevations snow led to extensive flooding in the Idaho Panhandle and as far south as the Clearwater Basin in late January and February. April was snowy and cool. Snowpacks averaged about 120 percent of normal in 1995 (Natural Resources Conservation Service, 1995). All of the primary and secondary sites were observed to or probably reached bankfull in 1995 (except Johns Creek). Discharges peaked at 150 percent of bankfull on average. Most streams remained higher than normal during the cool summer. The peak discharges in 1995 at sites correspond on average to 4.4 year recurrence interval flows.

Flow duration curves

Flow duration curves are important descriptors of hydrology necessary for the purpose of estimating total water yield and sediment yield. Two important issues arise with respect to the generation of these curves - the completeness of the existing record and the representativeness of the period of record. Most stream gages (other than USGS gages) in this region are operated from

snowmelt to freeze-up which is approximately early April to the end of October. To estimate the duration of flows during periods when gages were not operating, either due to seasonal shutdown or to equipment malfunction, the gages with partial records were correlated to nearby gages that operated year-round. By correlation, missing portions of the hydrographs were estimated. The second issue, the representativeness of the existing record, arises when the flow record is insufficiently long to include the typical range of flows associated with climatologic variation. To estimate the duration of flows over the longterm, sites with short period records were correlated to sites with a long period of record.

The method we developed (Moog et al., in prep.) to estimate these unmeasured flows is a modification of a method suggested by Hirsch (1982). The characteristics of the distribution shape, serial correlation, and seasonality associated with the record from a base station (with a long flow record) are transferred to the short-record station to augment the short record. The resulting time series of daily discharges is intended to be a plausible estimate of an actual record for the short-record site were it to exist.

For paired data having positive correlation the maintenance of variance estimation (MOVE.1) equation (Hirsch, 1982) is written

$$\hat{y}(i) = m(y) + \frac{S(y_1)}{S(x_1)}\left(x(i) - m(x_i)\right)$$

where y is the short record, x is the base record, subscript 1 indicates a subset consisting of concurrent dates, S is the standard deviation, m is the mean, and ^ indicates an estimated value. Note that there is no explicit pairing of values between x and y. This is equivalent to an ordinary least squares regression with r set to 1. Consequently the mean and variance of estimated y for the concurrent period equal the respective values for y_1.

The MOVE.1 technique is a linear function. Scatterplots of the concurrent data sets used to estimate the slope and intercept of this function should, therefore, display an essentially linear pattern. When a long term station is selected to extend a short-term station's discharge record, attempts are made to match the station's size, proximity, elevation, among other factors in the expectation that hydrological responses will be similar. However, the concept of hydrological similarity is complex and matching easily measurable characteristics does not always ensure that scatterplots of the concurrent records show linear patterns. In addition, the set of nearby stations with long discharge records is often small so that matches must sometimes be made from limited data sets.

Therefore, the best available long-term stations may show scatterplots of the concurrent data sets having curved point patterns and uneven variation over the range of flows of the long-term station. An obvious approach to this situation is to transform the discharges from one or both stations to more closely approximate a linear function-constant variance relationship, apply the

MOVE.1 procedure to the transformed data, and then back-transform to original coordinates. Hirsch (1982) used this general approach by taking logs of the discharges.

A widely used family of transformations is the power transformations discussed by Box and Cox (1964). The scaled system of power transformations can be written as:

$$v^{(\lambda)} = \begin{cases} (v^{\lambda} - 1) / \lambda & \text{if } \lambda \neq 0 \\ \ln \lambda & \text{if } \lambda = 0 \end{cases}$$

in which $v^{(\lambda)}$ is the transformed value of v and λ is the transformation parameter. A useful property of power transformations is that increasing or decreasing λ produces gradual changes in the effects on the point pattern. This system includes most common transformations; reciprocal, logarithm, square root, no transformation, and square.

We developed a program to visually select values of λ to fit the concurrent data sets. Various values of λ can be tested and plotted. The program can rapidly recompute and present a new plot reflecting new parameter values. When a combination of transformations is selected for both variables the point pattern can be fitted by a straight line which can be subtracted to display the residuals.

The visually selected values of λ to fit the concurrent data sets did not always produce ideal point patterns since the relationships between the stations result from complex relationships that cannot be fully represented by a linear function. However, the transformed data were much more linear and had more constant variance than the untransformed data. The MOVE.1 technique was then applied to these transformed data sets, the records extended, and the extended records back-transformed to original units. The base station selected for extending short records as well as the length of the respective records are listed in Table 4. In some cases, the actual record length was greater than that indicated but was not used because of concerns regarding data quality or methodology.

Table 4 - Flow extensions

Stream	Years of Record	Base Station	Years of Record	Years
Blackmare	1990-94[a]	SF Salmon R.@ Krassel	1967-82, 86,90-95	31
Canyon Cr	1992-95	Selway R. @ Lowell	1911-12, 1930-95	66
Catspur Cr	1987-95	NF Clearwater	1968-95	27
Dollar Cr	1990-94[a]	SF Salmon R.@ Krassel	1967-82, 86,90-95	31
Eggers Cr	1966-93	not extended	1966-93	27
Fish Creek	1992-95	Selway R. @ Lowell	1911-12, 1930-95	66
4 July Cr	1994-95	Valley Cr @ Stanley	1921-72, 1992-95	54
Hawley Cr	1989-95	Squaw Cr nr. Clayton	1971-95	24
Herd Cr	1994-95	Valley Cr @ Stanley	1921-72, 1992-95	54
Johns Creek	1986-95	SF Clearwater @ Stites	1965-95	30

Little Buckhorn	1990-94[a]	SF Salmon R.@ Krassel	1967-82, 86,90-95	31
Little Slate Cr	1986-95	Lt. Salmon R.	1952-54, 57-95	40
Lolo Creek	1986-95	Lolo Cr. nr. Greer	1980-95	15
Marsh Cr	1994-95	Valley Cr. @ Stanley	1921-72, 1992-95	54
Rapid River	1986-95	Salmon R. @ White Bird	1911-95	84
Red River	1986-95	SF Clearwater @ Stites	1965-95	30
SF Red R	1986-95	SF Clearwater @ Stites	1965-95	30
Squaw Cr	1989-95	Squaw Cr nr. Clayton	1971-95	24
Squaw Cr	1971-95	not extended	1971-95	24
Thompson Cr	1973-95	not extended	1973-95	22
Trapper Cr	1986-95	SF Clearwater @ Stites	1965-95	30
Valley Cr	1921-72, 92-95	not extended	1921-72, 1992-95	54
WF Buckhorn	1990-94[a]	SF Salmon R.@ Krassel	1967-82, 86,90-95	31

[a]Data collected includes five snowmelt hydrographs.

The cumulative frequency of the flows at sites is shown in Figures 7a and 7b. There is gross similarity in the structure of most curves which in part reflects the similarity of the hydrologic regime at sites - a snowmelt driven hydrograph. Hawley Creek, Lolo Creek and Squaw Creek near Salmon have a relatively smaller range of flows compared to the other streams. This may reflect a very large proportion of groundwater input to the stream (B. Riefenberger, pers. comm., 1995; B. Spiegal, pers. comm., 1997) (*c.f.* Whiting and Stamm, 1995).

Extension increased the magnitude of the mean annual discharge (Table 5) over the short period values for most sites. This is because much of the record at many sites is from the mid-1980s to 1995, a period including many years of drought. The ratio of the mean annual discharge to the bankfull discharge averages 0.21 at sites. In his study of Salmon River tributaries, Emmett (1975) found that the ratio of mean annual discharge to bankfull discharge averaged about 0.25 and that the ratio climbed from about 0.20 for small drainage areas to 0.27 for larger drainage areas.

Bankfull discharge is reached or exceeded on average of 9.2 days per year at sites. The range is from less than a day to 24 days per year.

Flood frequency

The recurrence interval of instantaneous peak flows was calculated by the Log Pearson III method (Water Resources Council, 1967). For Blackmare, Dollar, and WF Buckhorn Creeks, a two station comparison technique was used to estimate the recurrence interval of flows (US Geological Survey, 1981). At Fourth of July, Herd, and Marsh Creeks, there were only two years of record which is too short for a meaningfull estimate of flood frequency using the Log Pearson method. For these streams the annual peak of the mean daily flows during 1994 and 1995 were assigned the frequency of the corresponding flows at Valley Creek (the stream serving as the base record) and the frequency of bankfull and effective discharge interpolated between these values. The recurrence interval of the bankfull discharge averages 2.1 years with a range of 1.0 to 4.8

years (Table 5).

Sediment rating curves

The bedload transport rate measured at various discharges was plotted for each site (Appendix B). Bedload was determined herein as material collected in the Helley-Smith sampler coarser than 0.85 mm, the calculated approximate upper limit to sizes moved in suspension at these sites under the studied flows using the criterion for suspension that the shear velocity must be greater than the particle fall velocity (Bagnold, 1966 as discussed by Sumer et al., 1996).

A best fit regression of the form

$$Q_S = k\, Q^x \qquad (1)$$

was fit to the flow and bedload data. Q_S is the bedload transport rate in tonnes per day, k is a constant, Q is the flow discharge in cumecs, and x is a real number. Typically two bedload measurements were made during each visit to the site. If stage readings were frequent, each bedload measurement was associated with a distinct flow discharge, otherwise the two bedload measurements were associated with a single discharge. Table 5 presents the value of the exponent x in the equation. The mean value is 2.44 (S.D.= 0.61) while the median value is 2.37. which is within the range of values found in other studies.

An alterative model for bedload transport of the form

$$Q_S = j\,(Q - Q_c)^x \qquad (2)$$

was tested at a number of sites. Q_c is the discharge above which bedload begins to move and was estimated by iteratively solving for the value of Q_c in equation 2 that maximized the correlation coefficient (r^2). At the primary sites where data was collected by the same crews during two years of flow, Q_c was about 10% of bankfull discharge and about one-half the mean annual discharge. At these sites the model is consistent with the concept of a critical flow for the initiation of bedload transport. At many other sites, Q_c was often negative. We believe that this is not physically meaningfull. This alternative model was not used in subsequent analyses in this report.

At selected sites[3], the relationship between bedload and flow discharge was examined for hysteresis in bedload transport. Annual clockwise hysteresis was demonstrated in which for a given discharge above a threshold discharge there was greater transport before the threshold discharge and less transport after the threshold. The threshold discharge is greater than the mean annual flow and varies from about one-third to one-half the bankfull discharge (Moog and Whiting, manuscript).

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[3]Little Slate Creek, Lolo Creek, Rapid River, Red River, SF Red River, and Trapper Creek.

Table 5 - Characteristics of sediment transporting flows

Stream	Qma (m^3/s)	Bedload Exponent	Qs ($t\ km^{-2}\ y^{-1}$)	Q bkfl (m^3/s)	RI (yr)	Q eff (m^3/s)	RI (yr)
Blackmare	1.11	2.27	2.19	4.73	1.1	5.24	1.2
Canyon Cr	1.31	2.57	0.95	6.48	3.7	4.93	1.3
Catspur Cr	0.334	2.70	1.04	2.36	1.4	1.70	1.1
Dollar Cr	0.988	2.37	5.21	6.43	1.1	4.64	1.1
Eggers Cr	0.0168	1.63	5.54	0.0478	1.2	0.0170	1.04
Fish Creek	6.20	3.42	0.39	20.9	1.1	23.3	1.2
4 July Cr	0.425	3.06	0.44	3.88	1.5	2.01	1.1
Hawley Cr	0.535	2.79	0.61	1.33	2.7	0.47	1.06
Herd Cr	1.31	2.75	1.73	5.46	1.4	5.89	1.5
Johns Creek	4.47	2.13	0.03	49.0	4.8	15.77	1.1
Little Buckhorn	0.188	2.30	1.71	- -	- -	0.708	2.8
Little Slate Cr	3.11	1.66	0.17	13.0	2.4	7.73	1.5
Lolo Creek	2.51	1.76	0.44	11.7	2.3	6.88	1.05
Marsh Cr	3.79	2.55	3.99	20.8	1.6	18.3	1.5
Rapid River	4.30	2.17	0.72	17.7	2.3	15.9	1.9
Red River	2.07	2.25	2.95	9.34	1.3	9.51	1.3
SF Red R	1.24	1.94	0.62	7.25	1.9	5.61	1.3
Squaw Cr	0.110	1.75	0.16	0.623	5	0.365	1.8
Squaw Cr	0.903	2.77	0.80	5.12	1.6	8.04	2.6
Thompson Cr	0.447	3.34	2.64	2.48	1.6	3.40	2.3
Trapper Cr	0.360	1.85	2.12	2.56	2.6	1.67	1.1
Valley Cr	5.63	3.93	6.93	28.6	2.0	23.8	1.5
WF Buckhorn	1.03	1.93	1.37	5.72	1.2	4.98	1.0

Average annual yield of bedload (Table 5) averages 1.86 $t\ km^{-2}\ y^{-1}$. There is large scatter about the relation that we attribute in part to different basin characteristics (geology, slope, precipitation, and landuse) and to the size of the Helley-Smith sampler relative to the bed material size. In general, we measured and predicted less transport on an annual basis in the streams with larger particles that those with smaller bed sediment. The sediment coarser than 0.85 mm represents on average 58 percent of the sediment collected in the Helley Smith sampler (range = 45-72%).

Bedload size distribution -

The coarsest size of grains in transport increases as the discharge increases (Figure 8). Only data from primary sites is shown because the characterization of the particle sizes was most detailed for these sites. Results at other sites are substantively similar. The increase in particle size is nearly linear (exponents to the power fit range from 0.93-1.32) with discharge and shows large scatter - almost an order of magnitude variation at any discharge. The scatter is not surprising given the probabilistic nature of sediment entrainment and transport (Einstein, 1948; Dietrich and

Whiting, 1989).

The bedload is finer than the material making up the bed surface and subsurface (Table 6). The bedload size reported is the transport- and frequency-weighted median grain diameter. Bedload is often assumed to be similar to the subsurface material. Because the orifice of the Helley-Smith sampler limits the size of collected grains, the subsurface size distributions was truncated at 32 mm and the median diameter of the truncated samples recalculated. The bedload is finer than the subsurface material as indicated by the value of D* - the ratio of bedload and subsurface material D_{50} (Lisle, 1995).

Most of the bedload (40-90%) is sand size or finer (Table 6). Other workers (e.g. Leopold, 1995) have similarly reported that much of the load in gravel and cobble bed channels is sand.

The ratio of the size of median surface particle to the size of the median subsurface particle averages 3.28 for eight of the sites and ranges from 1.8 to 5.0.

Table 6 - Surface, subsurface and bedload sizes

Stream	Bed surface D_{50} (mm) [1]	Subsurface D_{50} (mm)	D_{50} of load (mm)	% sand in bedload[2]	Truncated $D_{50\,ss}$ [3]	D*
Johns Cr	205	56	5.7	85	-	-
Little Slate Cr	102	31	1.4	90	9.2	6.6
Lolo Cr	68	20	1.4	83	10.0	7.1
Rapid River	92	31	1.9	63	9.1	4.8
Red River	39	20	2.4	80	6.9	2.9
SF Red River	107	26	4.0	80	8.0	2.0
Trapper Cr	85	17	3.1	75	8.7	2.8
Valley Cr	53	29	3.0	59	8.9	3.0
Fourth July Cr	51	-	-	74	-	-
Herd Cr	67	-	-	56	-	-
Marsh Cr	57	-	-	40	-	-
Squaw Cr	43	-	-	73	-	-
Thompson Cr	66	-	-	87	-	-

[1] Surface size at site of subsurface sample if one taken.

[2] Average of material caught in the Helley-Smith sampler in 1994 and 1995.

[3] Subsurface grain size distribution truncated to sizes to less than 32 mm.

Painted rock experiments -

The orifice of the Helley-Smith bedload sampler limits the size of bedload than can be measured during sampling. The probabilistic nature of sediment transport (Einstein, 1948) means that the movement of the larger particles is infrequent and the likelihood that a sampler will be in position to catch such particles (even if they could fit into the sampler) is very low (Dietrich and

Whiting, 1988). One method for estimating the range of sizes that are in transport is to place painted rocks in the stream (e.g., Leopold, 1994; Leopold and Emmett, 1981). Painted rocks spanning the range of D_{25} to D_{90} were placed early in the 1995 snowmelt season at primary sites (with the exception of Marsh Creek) by our personnel and at select secondary sites (Rapid River, Red River, SF Red River, and Valley Creek) by US Forest Service personnel.

The painted rock experiments suggest that all particles up to at least the D_{90} of the bed material were capable of being moved by the bankfull and higher flows of 1995 (Figures 9a and 9b). Similarly Andrews (1984) documented that a fraction of the rocks moved several times during the snowmelt season suggesting that initial placement does not explain mobility of these sizes. It has been previously reported that there is no relationship between distance moved and grainsize (Leopold et al., 1964; Leopold and Emmett, 1981). There is some suggestion in this data that smaller particles moved further than coarser particles, but the magnitude of the differential translation is difficult to determine since recovery of the smaller particles was poor, particularly at primary sites and at Rapid River.

Suspended load and concentrations -

Figure 10 presents the rating curves for suspended load at the six primary sites. The rating equations for total concentration of suspended sediment are given below in Table 7 as well as the load of each stream at bankfull discharge for comparison with bedload at bankfull discharge. The bedload presented here includes all sediment caught in the bedload sampler and may include some sizes likely to have moved in suspension. Bedload is a relatively small proportion (7-33 %) of the suspended load at bankfull although this may be a minimum estimate since bedload coarser than 76 mm would be truncated by the sampler orifice.

Table 7 - Suspended load concentrations and yields

Stream	Rating equation, C (mg/L) =	Range of measured C (mg/L)	Suspended load at bankfull (t/d)	Bankfull bedload[1] (t/d)	Bedload / Suspended Load
Fourth July	$0.0819\ Q^{1.31}$	0.10 - 75.8	51.6	5.87	0.11
Herd	$0.116\ Q^{1.35}$	0.29 - 203	141	15.5	0.11
Marsh	$0.318\ Q^{0.508}$	0.35 - 29.6	9.08	27.6	0.33
Squaw	$0.109\ Q^{1.20}$	0.12 - 106	23.7	6.50	0.27
Thompson	$0.0867\ Q^{1.49}$	0.18 - 67.5	68.1	4.67	0.07
Valley	$0.0376\ Q^{0.850}$	1.1 - 42.1	13.5	172	0.08

[1] all sediment collected in the sampler

Determining the importance of various flows

The field data collected and the analysis is the basis for examining the nature of the flows

transporting the bulk of sediment in the upland headwater channels of the Intermontane West. Specifically we examine what percentage of the sediment is moved by different flows, and the frequency of events moving the most material (loosely called effective discharge), and the tie between effective discharge and properties of the channel.

Bedload Effective Discharge

The effective discharge estimation procedure follows the general approach of Wolman and Miller (1963) and Andrews (1980). A magnitude-frequency analysis is used to see which flows move the most material over time. Unlike many others, we have estimated effective discharge of the bedload based upon measured sediment rating curves as opposed to calculated bedload. Furthermore, calculation of the effective discharge is not based upon 'bining' of flows into discharge increments (i.e. Andrews, 1980) but rather is based upon the product of the sediment rating curve (*magnitude*) and discharge probability density function (*frequency*). Probability density functions (pdf) were evaluated at 100 points covering the discharge domain using the S-PLUS software function 'density' with kernel estimates based on Gaussian windows. That is, for each of these 100 points, a function (the window) is centered on the point and the heights of the window at each data point are summed. This sum, after normalization, is the value of the pdf at that discharge. The window is a Gaussian curve with a standard error equal to 0.025 times the width of the discharge domain. This was found by experience to smooth out likely idiosyncrasies in the pdf and retain the more fundamental features.

As a surrogate for all bedload, the discharge of sediment finer than 76 mm (the orifice size of the sample) is used here. Furthermore all sediment likely to have been moving as suspended load was excluded as described earlier. For almost all flows and all sites, this corresponds to sizes between 0.5 and 1.0 mm and so a standard size of 0.85 mm was used as the lower estimate of bedload sizes. On average the sediment yield coarser than 0.85 mm represents 59% of the sediment yield based upon all sizes caught in the sampler.

Long-term flow frequency was determined by correlating local short records to other longer records using the technique described earlier (Moog et al., in prep.) which builds upon the method outlined by Hirsch (1982).

The effective discharge increases as the bankfull discharge increases (Figure 11). Effective discharge at sites averages 80 percent of the bankfull discharge and ranges from 34 to 157 percent. Several of the lowest effective discharges relative to bankfull are at sites with comparatively small ranges in discharge whereas some of the largest effective discharges are at sites with large ranges in discharge; this observation will be discussed later.

The recurrence interval of effective discharge averages 1.5 years whereas the recurrence interval for bankfull discharge is 2.1 years (Table 5). The median percent of time effective discharge is equalled or exceeded is 3.8 (range = 1.0 - 47%; average = 6.5%) or 14 days per year.

Effective discharge plots for sites are collected in Appendix C.

Cumulative curves

Effective discharge is just one measure of the sediment transport regime of a channel - in particular it is the steepest part of the cumulative curve relating water and sediment transport. There is substantial information contained in curves relating the cumulative percent of bedload moved and to the cumulative percent discharge as shown in Figure 12. Almost one-half of the water (45%), that water associated with the lower discharges, is used to move the first 10 percent of bedload. One-half of the bedload is moved by the lowest 81 percent of the flow. The upper 2.5 percent of the flow moves 10 percent of the bedload (Table 7). At an individual stream, the greater the exponent to the bedload rating curve, the greater proportion of bedload moved by the higher flows (Figure 13).

Table 7 - Cumulative percent of sediment and water

Stream	Cumulative percent of water corresponding to indicated cumulative percent of sediment								
	10	20	30	40	50	60	70	80	90
Blackmare	46.3	58.6	67.4	74.5	80.5	85.8	90.4	94.5	97.7
Canyon Cr	48.4	60.9	69.8	76.9	82.7	87.6	91.7	95.2	98.0
Catspur Cr	52.4	64.7	72.8	78.8	83.8	88.2	92.0	95.5	98.6
Dollar Cr	48.3	60.1	68.6	75.5	81.5	86.6	91.0	94.7	97.7
Eggers Cr	23.3	42.1	56.6	67.3	75.3	81.9	87.6	92.5	96.6
Fish Creek	58.9	70.7	78.7	84.5	88.9	92.4	95.1	97.1	98.8
4 July Cr	58.6	69.4	76.8	82.5	87.2	90.9	94.0	96.6	98.8
Hawley Cr	24.9	44.7	60.7	72.4	79.9	85.9	90.7	94.6	97.6
Herd Cr	53.7	64.9	72.7	78.9	84.1	88.6	92.3	95.5	98.2
Johns Creek	41.5	55.1	64.7	72.6	79.1	84.8	89.7	94.1	97.7
Little Buckhorn	44.2	57.2	66.0	73.0	79.1	84.3	89.1	93.4	97.2
Little Slate Cr	23.5	38.1	49.1	58.5	66.9	74.6	81.7	88.4	94.5
Lolo Creek	26.1	39.9	50.8	60.3	68.7	76.3	83.4	89.8	95.4
Marsh Cr	57.7	69.5	77.5	83.7	88.5	92.2	95.3	97.8	99.3
Rapid River	42.5	56.4	65.6	72.8	78.9	84.3	89.0	93.2	97.0
Red River	50.2	63.4	72.2	79.0	84.4	89.0	92.7	95.9	98.4
SF Red R	38.0	52.3	62.4	70.5	77.3	83.2	88.3	92.9	96.9
Squaw Cr (USFS)	26.5	41.8	52.6	61.4	69.1	76.2	82.9	89.0	94.7
Squaw Cr (USGS)	60.9	71.7	78.9	84.2	88.4	91.8	94.7	97.0	99.0
Thompson Cr	70.2	80.9	86.9	91.0	93.9	95.9	97.3	98.4	99.4
Trapper Cr	35.1	49.4	59.8	68.3	75.5	81.8	87.3	92.2	96.6
Valley Cr	67.3	76.7	82.8	87.5	91.2	93.9	96.2	98.0	99.4
WF Buckhorn	35.9	48.7	58.3	66.3	73.5	80.0	85.9	91.2	96.0
AVERAGE	**44.99**	**58.16**	**67.48**	**74.80**	**80.81**	**85.93**	**90.37**	**94.24**	**97.54**

An average of 6 percent of bedload is moved by flows below mean annual discharge while 37

percent of the bedload is moved by flows above bankfull discharge. Appendix D collects the cumulative curves for water, sediment and time as a function of discharge.

Discussion

The twenty-three alluvial headwater streams studied in central and northern Idaho span a large range of channel gradients, grain sizes, and watershed size. To the degree that the streams cover much of the variation seen in headwater streams they are representative of such streams and results and conclusions drawn from such streams should be applicable to alluvial headwater streams in general.

Surface particle size generally increases and gradient decreases with drainage area in headwater streams. Bankfull discharge increases with drainage area. The exponents for width, depth and velocity in hydraulic geometry are 0.47, 0.32, and 0.22, respectively. The regional relationships for hydraulic geometry determined here are similar to those found by Emmett (1975) for the Salmon River basin in Idaho.

The channel beds studied are armored; the ratio of surface to subsurface size averages 3.37 for the sites. Armouring has been linked (*cf.* Dietrich et al., 1989) to local supply that is less than the ability of the stream to transport that load. Supply limitations can give rise to armouring over small areas on the bed or over the entire bed. Observed clockwise hysteresis in bedload at discharges above a threshold corresponding to about one-third to one-half bankfull as described earlier is consistent with supply limitation inferred from the armoring. The generality of surface armouring at all sites as well as the consistency of observing clockwise hysteresis suggests that the supply limitations reflect watershed processes rather than local in-channel processes.

Most of the bedload is sand as has been found by others (e.g. Leopold, 1992). Sand makes up the majority of bedload at all stages. Suspended load is a larger contributor than bedload to the total amount of sediment carried by the stream channel. Even at bankfull discharge, bedload is only 7 to 33 percent of suspended load. The size of bedload particles caught in the bedload sampler increases as discharge increases. Painted rock experiments confirm that the grains making up the bed surface (grains up to at least D_{90}) are moved by bankfull flows.

The bedload is finer than the subsurface in streams for which subsurface information was available (Table 6). Lisle (1995) found that the ratio of the median particle size of bed material to the transport- and frequency-weighted mean of median bedload size (D*) decreased from ~3 toward unity as drainage area and bankfull discharge increased. D* was approximately 1 near a drainage area of 100 km^2 or a bankfull discharge of 50 m^3/s. Lisle (1995) used this result to suggest that the equal mobility concept (Parker and Klingeman, 1982; Andrews, 1983), while it may be applicable to larger streams, breaks down in smaller basins. Values of D* at sites are large

(2-7) which is consistent with selective transport of finer sizes (*cf.* Ashworth and Ferguson, 1989). The observation that the size of the coarsest particle in sampler increases with discharge is consistent with selective transport of the finer fraction (Figure 8).

The effective discharge is generally similar to, albeit slightly less than, the bankfull discharge. Effective discharge averages 80 percent of the bankfull discharge and the recurrence interval of effective discharge averages 1.5 years whereas the recurrence interval for bankfull discharge is 2.1 years (Table 4). The recurrence interval of effective discharge is similar to that reported by others (Andrews, 1980; Wolman and Miller, 1960; Pickup and Warner, 1976). The median percentage of time effective discharge is equalled or exceeded is 3.8 at all sites which is greater than the 0.35 to 3.0 % reported by others working in gravel bed streams (Andrews, 1980; Webb and Walling, 1982).

Others have reported similarity between bankfull and effective discharges (Andrews, 1980; Biedernharn et al., 1987; Leopold, 1992; Nolan et al., 1987; Pickup and Warner, 1976; Webb and Walling, 1982; Wolman and Miller, 1960) although all these reports except Leopold (1992) were for total or suspended load. Ashmore and Day (1988) found that the effective discharge for suspended sediment was a rarer and more extreme event in smaller drainage basins. Pitlick (1988) found that bedload effective discharge in northern California became an increasingly rare event as the gradient and bed material size increased. In the systems examined in Idaho, there is no evidence for effective discharge becoming a rare event as drainage basin size (Fig. 14a), median particle diameter (Fig. 14b) and gradient (Fig. 14c) vary.

While there is no obvious change in the frequency of effective discharge with basin size as others have suggested (Ashmore and Day, 1980; Pitlick, 1988), there is however an increase in the relative magnitude of effective discharge as the relative magnitude of rare events increases (Fig. 15). The relative magnitude of rare events is described by the discharge associated with an event with an exceedence probability of 0.1 % as scaled by the median discharge. Since the effective discharge is the product of magnitude and frequency, streams in which discharge is relatively larger for a given frequency of event, will have larger effective discharges. Spring-fed streams such as Hawley Creek and Squaw Creek with relatively small discharge ranges (Figure 7a, b) have relatively small effective discharges (respectively, 35 and 59% of bankfull discharge). On the other hand, flashy streams such as Thompson Creek and Squaw Creek have relatively large effective discharges (157 and 137 % of bankfull discharge). An inverse relationship exists between drainage area and the ratio of a magnitude event to the mean annual discharge (Kuiper, 1957). In so far as smaller basins tend to be flashier and more-extreme, less-frequent events are thought to play a more important role in smaller basins (Costa, 1974; Grant et al, 1991), one might expect effective discharge to increase in relative magnitude and become a less frequent event in smaller basins.

Effective discharge is the single flow moving the most bedload. In so far as it is only a

single discharge value, it is a rather incomplete descriptor of the transport regime. An average of 6 percent of bedload is moved by flows below mean annual discharge while 37 percent of the bedload is moved by flows above bankfull discharge. Almost one-half of the water (45%), that water associated with the lower discharges, is used to move the first 10 percent of bedload. The highest discharges are the most efficient in moving bedload in terms of the amount of water used. The upper 2.5 percent of the flow moves 10 percent of the bedload and the upper 19 percent of the flow moves half the bedload (Table 7). Webb and Walling (1982) found that 50 percent of suspended load was moved by 9% of the total discharge. At an individual stream, the greater the exponent to the bedload rating curve, the greater proportion of bedload moved by the higher flows (Fig. 13).

Andrews and Nankervis (1995) in their study of gravel bed streams reported that bed material (> 4 mm) began to move at approximately the 60 percent of the bankfull discharge and calculated that discharges less than the bankfull transported 39 percent of the annual bedload. On the other hand, we noted in Idaho that about 30 percent of bedload moved at flows below 60 percent of bankfull and that 60 percent of bedload is moved by discharges below bankfull. Given that Andrews and Nankervis excluded the finer bedload in their analysis, our results may be substantially similar.

Bedload effective discharge and bankfull discharge are similar in magnitude and are both moderately frequent events. This has been taken (*e.g.* Andrews, 1980) to indicate that channels are adjusted to the effective discharge. We would add that the relationships embodied as bankfull hydraulic geometry further link those discharges moving the most sediment to the creation and maintenance of the channel dimensions. We would emphasize that effective discharge is a conceptually powerful tool for understanding the flows moving sediment, but that effective discharge is a surrogate for describing all flows that by moving sediment making up the bed and bank create and maintain the geometry of the channel.

Conclusions

The study of the geometry and transport regime of headwater channels as well as the linkage between them points to the following conclusions.

1) Bankfull discharge is a moderately frequent event having an average recurrence interval of 2.1 years. Bankfull discharge is reached on average 9 days a year.

2) Progressively larger sediment is in motion as stage rises but the majority of bedload is sand at all stages. Bedload is finer than the bed material suggesting that there is size selective transport.

3) Hysteresis is seen in the bedload such that more transport is observed early in the hydrograph. This and the surface armor provide strong evidence for the supply limits on these channels.

4) Effective discharge averages 80 percent of bankfull discharge and has a recurrence interval of 1.5 years. Effective discharge, as a percentage of bankfull discharge, is independent of basin size, grain size and gradient, at least in these streams, although effective discharge as a percentage of bankfull discharge increases as streams become flashier. Streams with only moderate rises in discharge during high flows have the smallest effective discharges.

5) Almost fifty percent of the water is used to move the first ten percent of the bedload. In contrast the upper 2.5 percent of the water moves ten percent of the bedload.

6) Little bedload (6 percent) is moved by flows below mean annual discharge while 37 percent of the bedload is moved by flows above bankfull discharge.

References

Andrews, E.D., 1980, Effective and bankfull discharges in the Yampa basin, Colorado and Wyoming: J. Hydrology, 46, 311-330.

Andrews, E.D., 1983, Entrainment of gravel from naturally sorted riverbed material; Geological Society of America Bulletin, 94, 1225-1231.

Andrews, E.D., 1984, Bed-material entrainment and hydraulic geometry of gravel-bed rivers in Colorado; Geological Society of America Bulletin, 95, 371-378.

Andrews, E.D., and J.M. Nankervis, 1995, Effective discharge and the design of channel maintenance flows for gravel-bed rivers, in Natural and Anthropogenic Influences in Fluvial Geomorphology, AGU monograph Series 89, p. 151-164.

Ashmore, P.E., and Day, T.J, 1988, Effective discharge for suspended sediment transport in streams of the Saskatchewan River basin; Water Resour. Res., 24, 864-870.

Ashworth, P.J., and R.I. Ferguson, 1989, Size-selective entrainment of bedload in gravel bed streams; Water Resources Research, 25, 627-634.

Bagnold, R.A., 1966, An approach to the sediment transport problem from general physics; US Geological Survey Prof. Paper 422-I.

Biedernharn, D.S., Little, C.D., and Thorne, C.R., 1987, Magnitude and frequency in large rivers, in Ragan, R.M. ed., Hydraulic engineering: Proc. 1987 Nat. Conf. Hydraulic Engineering: New York, Am. Soc. Civil Engineers, p. 782-787.

Box, G.E.P. and D.R. Cox, 1964, An analysis of transformations, J. of the Royal Statistical Society, Series B, 26, 211-246.

Carling, P., 1978, The concept of dominant discharge applied to two gravel-bed streams in relation to channel stability thresholds: Earth Surf. Proc. Landforms, 13, 355-367.

Costa, J.E., 1974, Stratigraphic, morphologic, and pelagic evidence of large floods in humid environments; Geology, 2, 301-303.

Dietrich, W.E., J.W. Kirchner, H. Ikeda, and F. Iseya, 1989, Sediment supply and the development of the coarse surface layer in gravel-bed rivers; Nature, 340, 215-217.

Dietrich, W.E., and P.J. Whiting, 1989, Boundary shear stress and sediment transport in river meanders of sand and gravel: in River Meandering, Ikeda, S. and G. Parker, ed., pp. 1-50, American Geophysical Union Water Resources Monograph 12.

Dunne, T. and L.B. Leopold, 1978, Water in environmental planning; W.H. Freeman, New York, 818 pp.

Edwards, T.K. and Glysson, G.D., 1988, Field methods for measurement of fluvial sediment; US Geological Survey Open File Report 86-531, 118 pp.

Einstein, H.A., 1948, Determination of rates of bedload movement; Proc. Fed. Interagency Sediment. Conf., p. 75-90.

Emmett, W.M., 1975, The channels and waters of the Upper Salmon River area, Idaho: US Geological Survey Professional Paper 870-A, 115 p.

Fenneman, N.M., 1931, Physiography of Western United States, McGraw-Hill Book Company, New York, 534 pp.

Grant, G. E., F.J. Swanson, and M.G. Wolman, 1990, Pattern and ongin of stepped-bed morphology in high gradient streams, Western Cascades, Oregon; Geological Society of America Bulletin, 102, 340-352.

Hipolito, J.N. and J.M. Leoureiro, 1988, Analysis of some velocity-area methods for calculating open-channel flow; Hydrological Sciences Journal, 33, 311-320.

Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques, Water Resources Research, 18(4), pp. 1081-1088.

Jarrett, R.D. 1984, Hydraulics of high-gradient streams; J. Hydraulic Eng., 110, 1519-1539.

Kuiper, E., 1957, 100 frequency curves of North American rivers; Am. Soc. Civil Engineers Proceedings, 83, 31 pp.

Leopold, L.B., 1992, Sediment size that determines channel morphology. In Dynamics of gravel-bed rivers, P. Billi, R.D. Hey, C.R. Thorne, and P. Tacconi, J. Wiley and Sons, p. 297-307.

Leopold, L.B., 1994, A view of the river; Harvard University Press, Cambridge, Massachusetts, 298 pp.

Leopold, L.B. and W.W. Emmett, 1981, Some observations on the movement of cobbles on a streambed; IAHS Symposium on the Measurement of Erosion and Sediment Transport, Florence, Italy, v. 2, p. 49-60.

Leopold, L.B., W.W. Emmett, and R.M. Myrick, 1966, Channel and hillslope processes in a semiarid area, New Mexico; US Geol. Surv. Prof. Paper 352 G.

Lisle, T.E., 1995, Particle size variations between bedload and bedmaterial in natural gravel bed channels; Water Resources Research, 31, 1107-1108.

Maley, T.S., 1987, Exploring Idaho Geology.

Montgomery, D.R. and J.M. Buffington, 1993, Channel classification, prediction of channel response, and assessment of channel condition; Report prepared fo rthe SHAMW committee of the Washington State Timber/Fish/Wildlife Agreement, 83 pp.

Moog, D.B. and P.J. Whiting, manuscript, Annual hysteresis in bedload rating curves.

Moog, D.B., R. Thomas, and P.J. Whiting, draft, The use of power transformations in discharge record extension.

Nash, D.B., 1994, Effective sediment-transporting discharge from magnitude-frequency analysis: J. Geology, 102, 79-95.

Natural Resources Conservation Service, 1994, Idaho Annual Data Summary- Water Year 1994; US Department of Agriculture, 28 pp.

Natural Resources Conservation Service, 1995, Idaho Annual Data Summary- Water Year 1995; US Department of Agriculture, 32 pp.

Nolan, K.M., T.E. Lisle, and H.M. Kelsey, 1987, Bankfull discharge and sediment transport in northwestern California; Erosion and Sedimentation in the Pacific Rim; IAHS Pub.165, 439-449.

Parker, G., and P.C. Klingeman, 1982, On why gravel bed streams are paved; Water Resources Research, 18, 1409-1423.

Pickup, G., and Warner, R.F., 1976, Effects of hydrologic regime on magnitude and frequency of dominant discharge: J. Hydrology, v. 29, p. 51-75.

Pitlick, J., 1988, Response of coarse bed rivers to large floods in Colorado and Calfornia; Ph.D. dissertation, Colorado State University, Ft. Collins, CO, 137 pp.

Rosgen, D.L., 1994, A classification of natural rivers; Catena, v. 22, p. 169-199.

Sumer, B.M., A Kozakiewicz, J. Fredsoe, and R. Diegaard, 1996, Velocity and concentration profiles in a sheetflow layer of moveable bed: J. Hydr. Engineering, 122, 549-555.

University of Idaho, 1995, Mean annual precipitation, 1961-1990, Idaho (map).

US Geological Survey, 1981, Guidelines for determining flood flow frequency; Bulletin 17 B.

US Geological Survey, 1994, Water Resources Data Idaho Water Year 1994; US Department Interior, 429 pp.

US Geological Survey, 1995, Water Resources Data Idaho Water Year 1994; US Department Interior, 443 pp.

Water Resources Council, 1967, A uniform technique for determining flood flow frequencies; Bulletin 15.

Webb, B.W., and Walling, D.E., 1982, The magnitude and frequency characteristics of fluvial transport in a Devon drainage basin and some geomorphic implications: Catena, 9, 9-23.

Whiting, P.J., and J.F. Stamm, 1995, Channel form and process in spring-dominated channels; Geomorphology, 12, 233-240.

Williams, P.L., 1961, Glacial Geology of the Stanley Basin, Idaho; Idaho Bureau of Mines and Geology Pamphlet 123.

Wolman, M.G., 1954, Method of sampling coarse river bed material, Trans. Am. Geophysical Union, 35(6), 951-956.

Wolman, M.G. and J. Miller, 1960, Magnitude and frequency of forces in geomorphic processes; J. Geology, 69, 54-74.

Acknowledgements

This work was supported by the US Forest Service as well as Case Western Reserve University. Jack King provided crucial assistance and suggestions. We would like to thank Nick Gerhardt, Gail Howard, Jim Paradiso, Betsy Rieffenberger, Sydney White, and Bob Kenworthy of the US Forest Service for providing data and field support. Assistance in the field was provided by Tom Becker, Jill Best, Jeff Byrnes, Shawn Chartrand, Molly Delany, Raymond Huang, Chris Kropf, and Chuck Martin.

Figure 1 - Locations of the primary and secondary sites: BL - Blackmare Creek, CY - Canyon Creek, CP - Catspur Creek, DO - Dollar Creek, EG - Eggers Creek, FH - Fish Creek, FJ - Fourth of July Creek, HD - Herd Creek, JO - Johns Creek, LB - Little Buckhorn Creek, LS - Little Slate Creek, LO - Lolo Creek, MA - Marsh Creek, RA - Rapid Creek, RD - Red River, SQ - Squaw Creek (near Clayton), SW - Squaw Creek (near Salmon), SR - South Fork Red River, TH - Thompson Creek, TR - Trapper Creek, VA - Valley Creek, and WB - West Fork Buckhorn Creek.

Figure 2 - Stream gradient decreases as drainage area becomes larger.

Figure 3 - Bedsurface grain size increases as drainage area becomes larger.

Figure 4 - Bankfull width and depth increase with drainage area.

Figure 5 - Bankfull discharge increases with drainage area.

Figure 6 - Hydraulic geometry at sites - bankfull depth, width and velocity as a function of bankfull discharge.

Figure 7 - Probability of exceedence for flows at sites - presented alphabetically in a and b. The similarity of most curves is due to the common snowmelt dominated hydrograph at sites. The exceptions are Hawley and Squaw Creek in which there is a large spring-fed component.

Figure 8 - The size of the coarsest particle caught in the Helley-Smith sampler increases as the discharge increases.

Figure 9 - Downstream displacement of painted rocks placed in two 20-rock transects per site at primary sites (a) and secondary sites (b). Recovered particles shown as filled squares; unrecovered particles as open squares.

Figure 10 - Suspended load rating curves for primary sites.

Figure 11 - Bankfull and effective discharge at sites. The line indicates a 1:1 relationship. Effective discharge averages 80 percent of bankfull discharge at sites.

Figure 12 - Cumulative curves for the percent of water used to move a given percent of bedload.

Figure 13 - The greater the exponent to the bedload rating curve, the greater the percentage of bedload moved by the upper 10 percent of the flow.

Figure 14 - There is no obvious trend in effective discharge with drainage area (a), median particle size (b), or stream gradient (c).

Figure 15 - The relative magnitude of effective discharge increases as the relative magnitude of rare events increases.

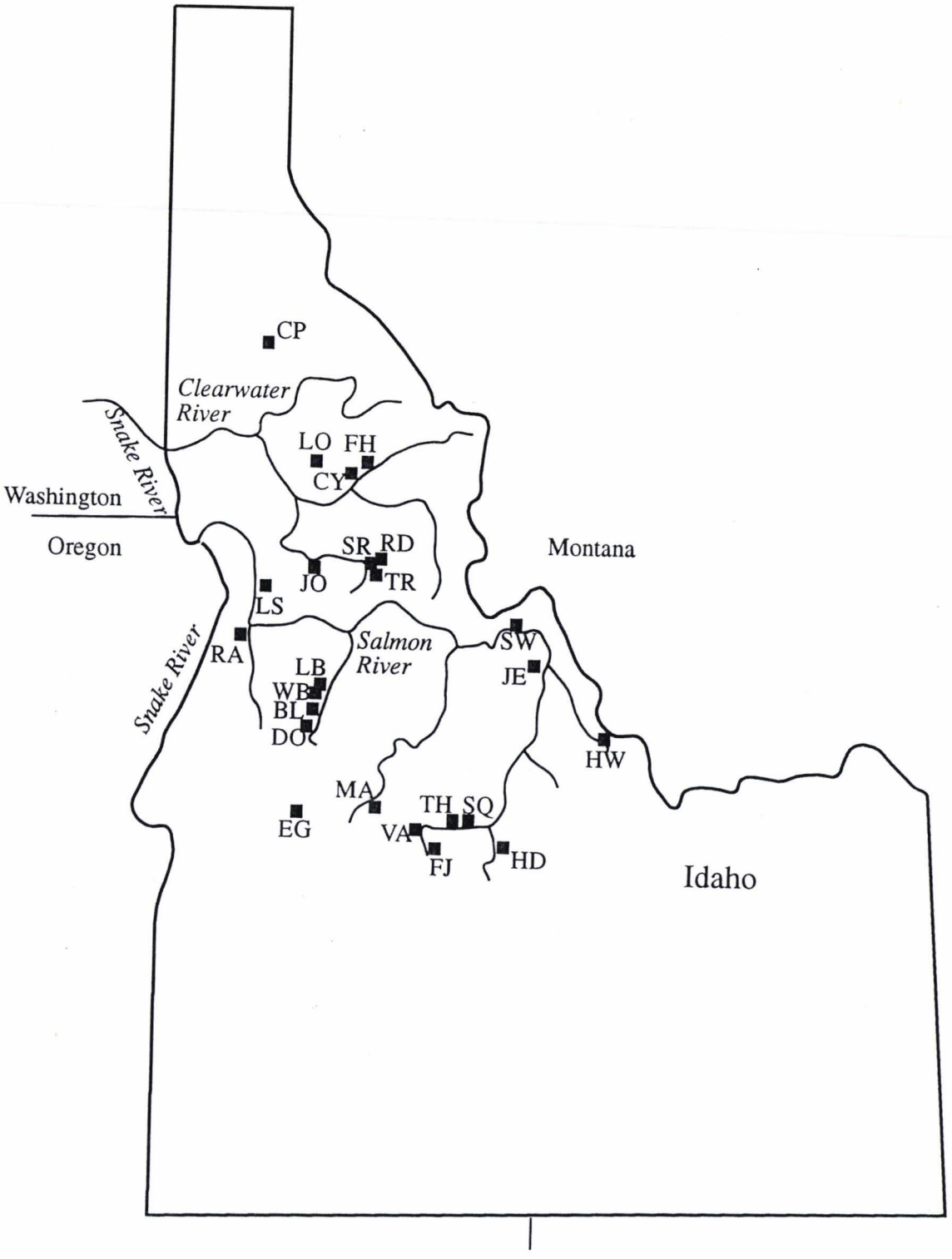

CP
Clearwater River
Snake River
LO
FH
CY
Washington
Oregon
SR
RD
JO
TR
Montana
LS
RA
Snake River
Salmon River
SW
JE
LB
WB
BL
DO
HW
MA
TH
SQ
EG
VA
FJ
HD
Idaho

Figure 1

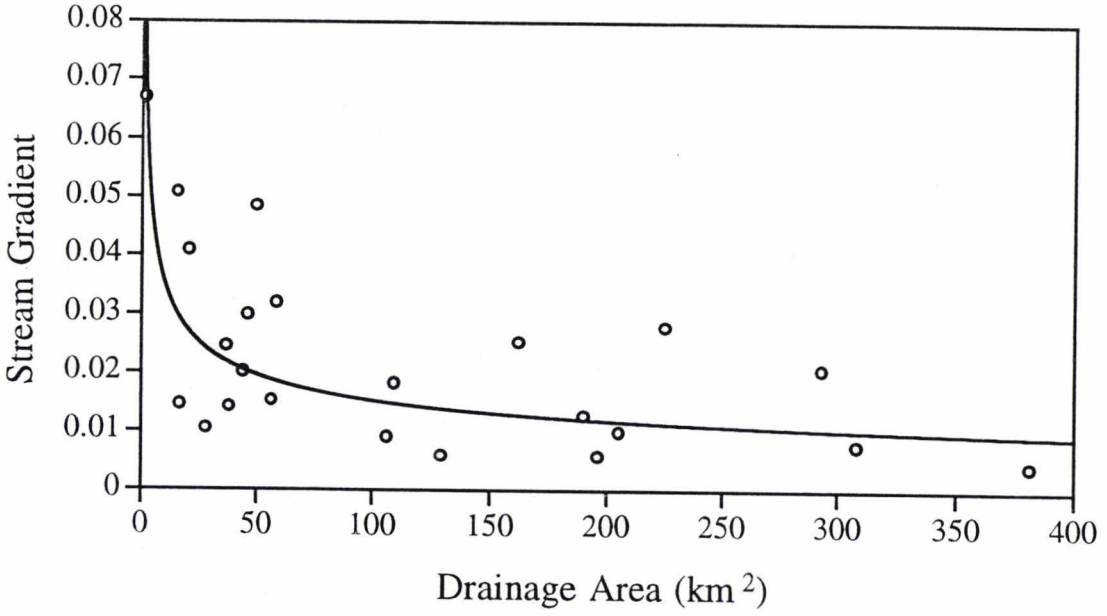


Figure 2

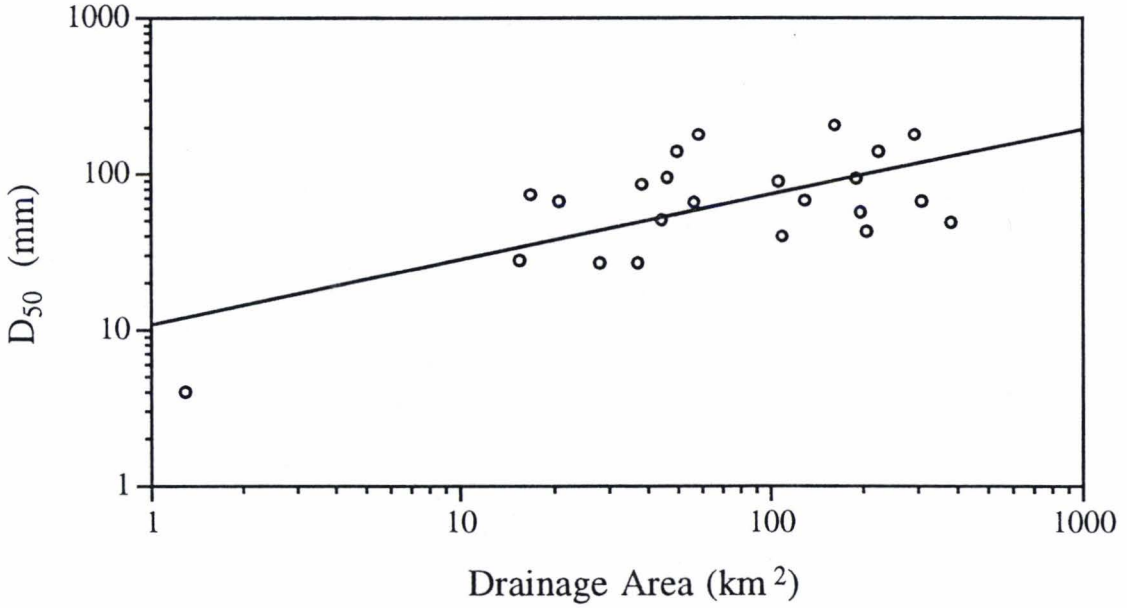


Figure 3

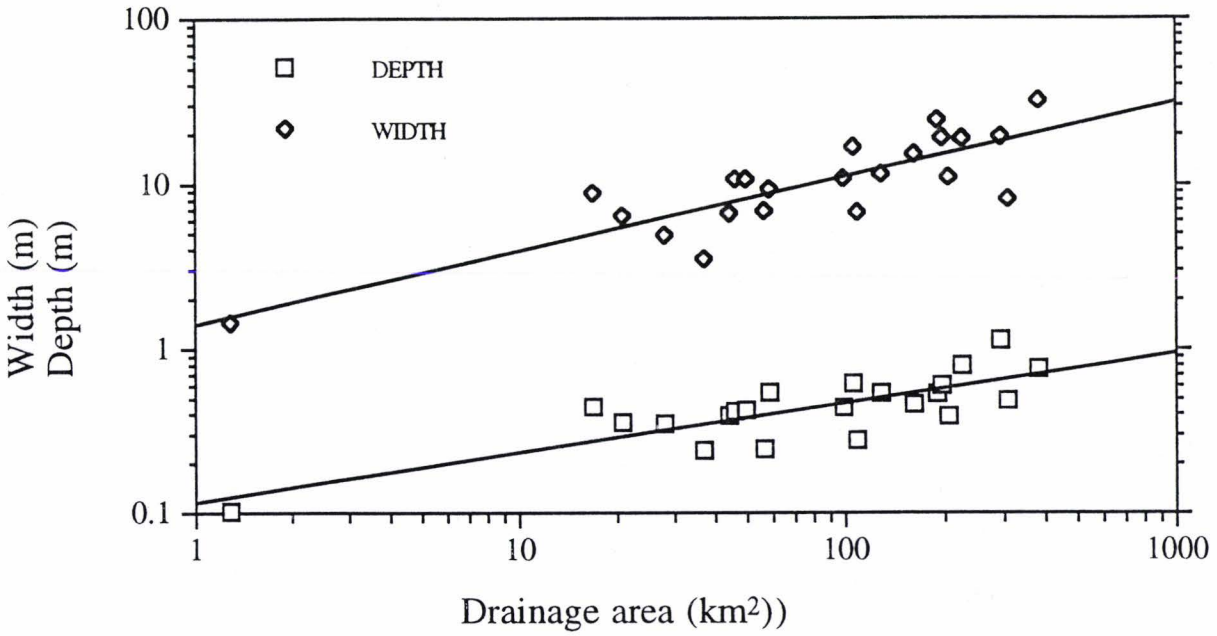


Figure 4

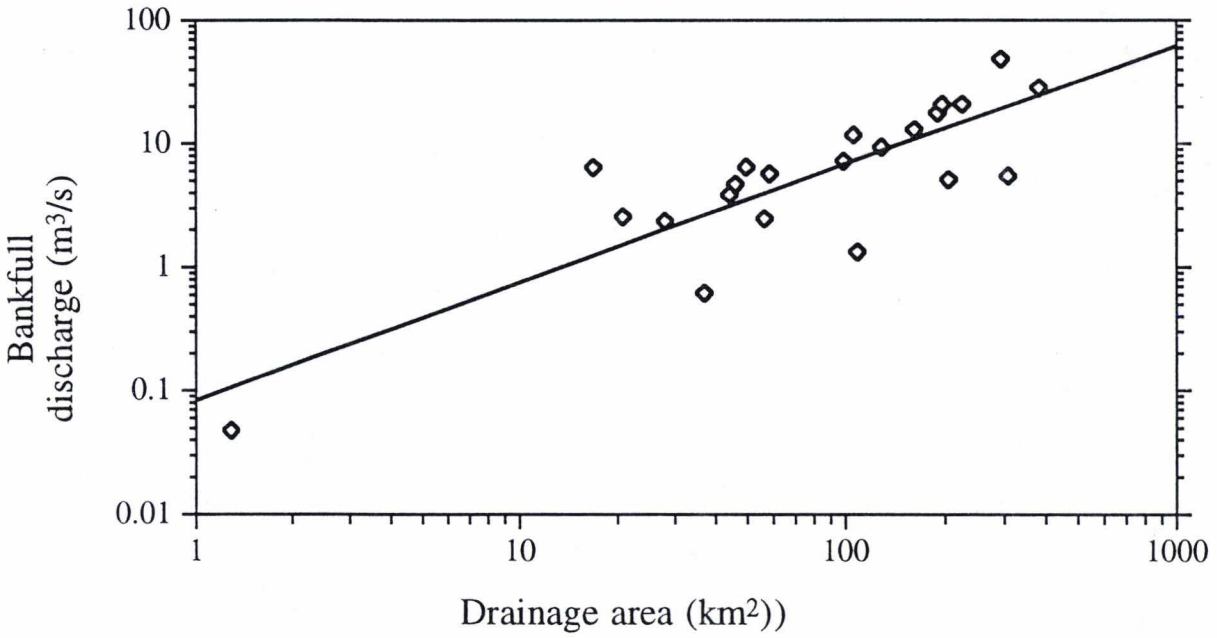


Figure 5

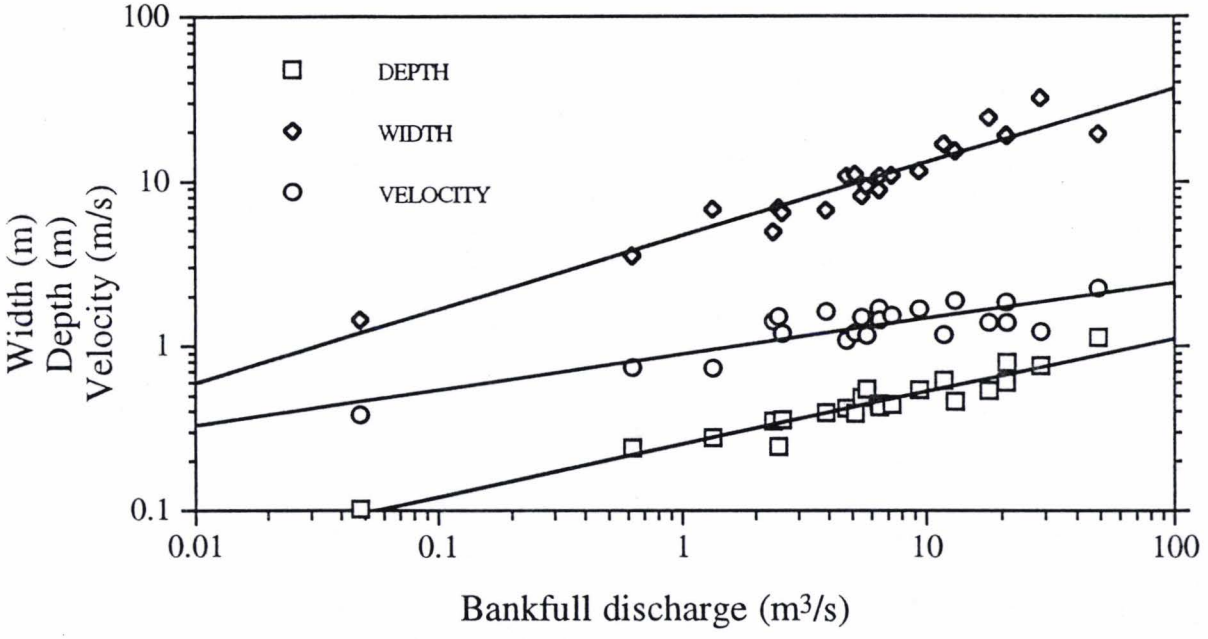

100
10
1
0.1
0.01
0.1
1
10
100
DEPTH
WIDTH
VELOCITY
Width (m)
Depth (m)
Velocity (m/s)
Bankfull discharge (m3/s)

Figure 6

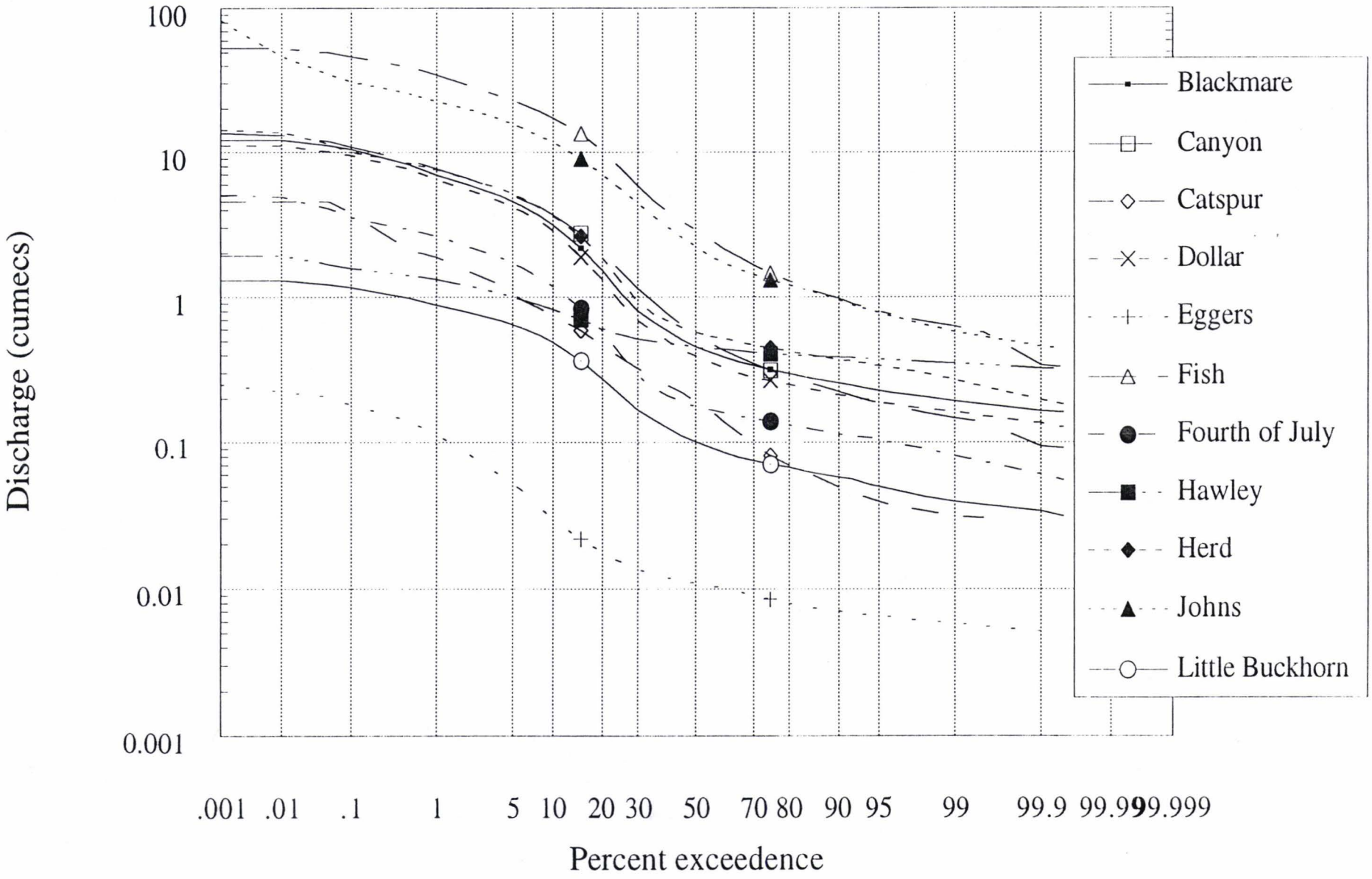

100
10
1
0.1
0.01
0.001
Discharge (cumecs)
.001 .01 .1 1 5 10 20 30 50 70 80 90 95 99 99.9 99.99 99.999
Percent exceedence
Blackmare
Canyon
Catspur
Dollar
Eggers
Fish
Fourth of July
Hawley
Herd
Johns
Little Buckhorn

Figure 7a

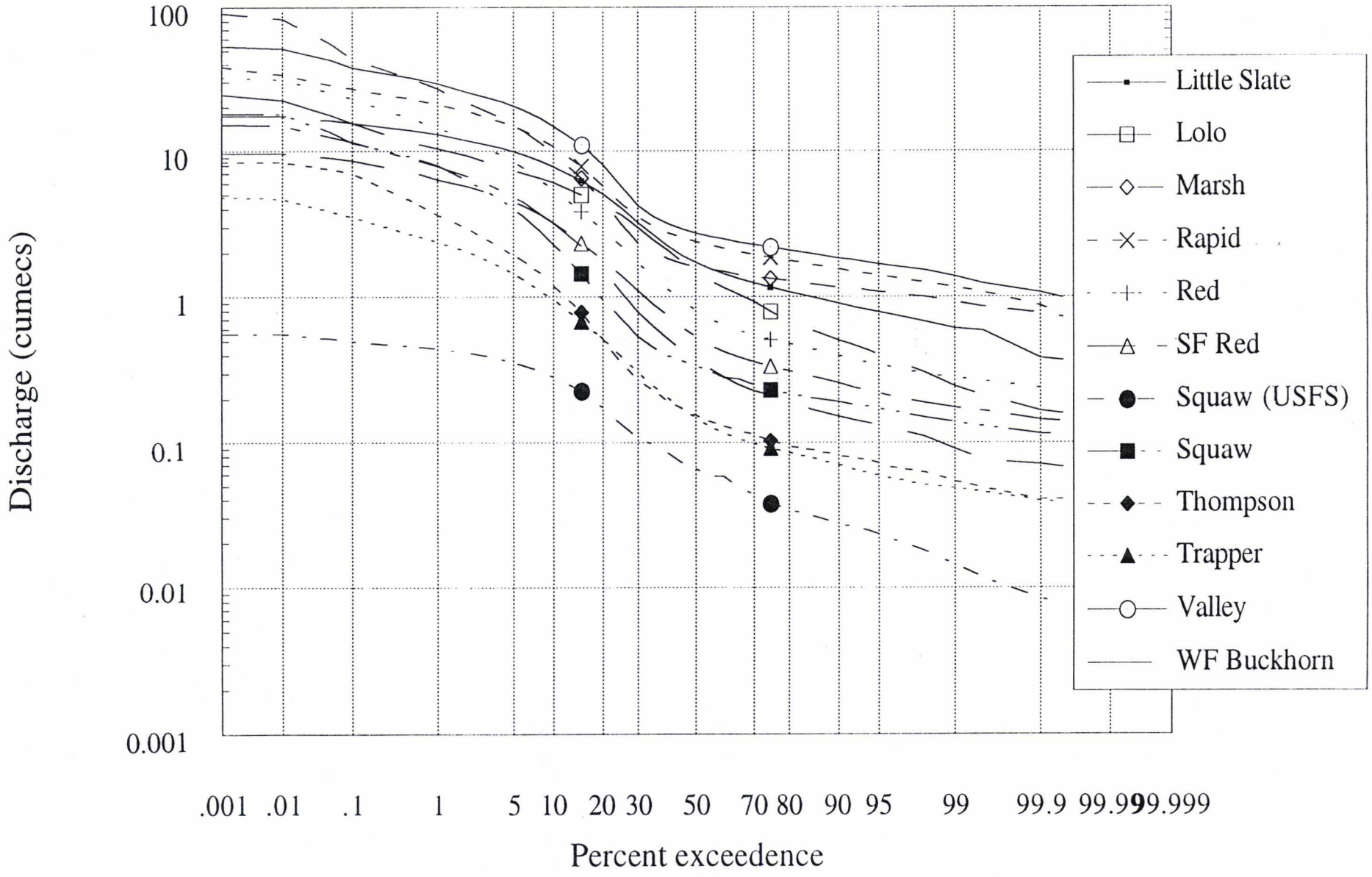

100
10
1
0.1
0.01
0.001
Discharge (cumecs)
.001 .01 .1 1 5 10 20 30 50 70 80 90 95 99 99.9 99.99 99.999
Percent exceedence
Little Slate
Lolo
Marsh
Rapid
Red
SF Red
Squaw (USFS)
Squaw
Thompson
Trapper
Valley
WF Buckhorn

Figure 7b

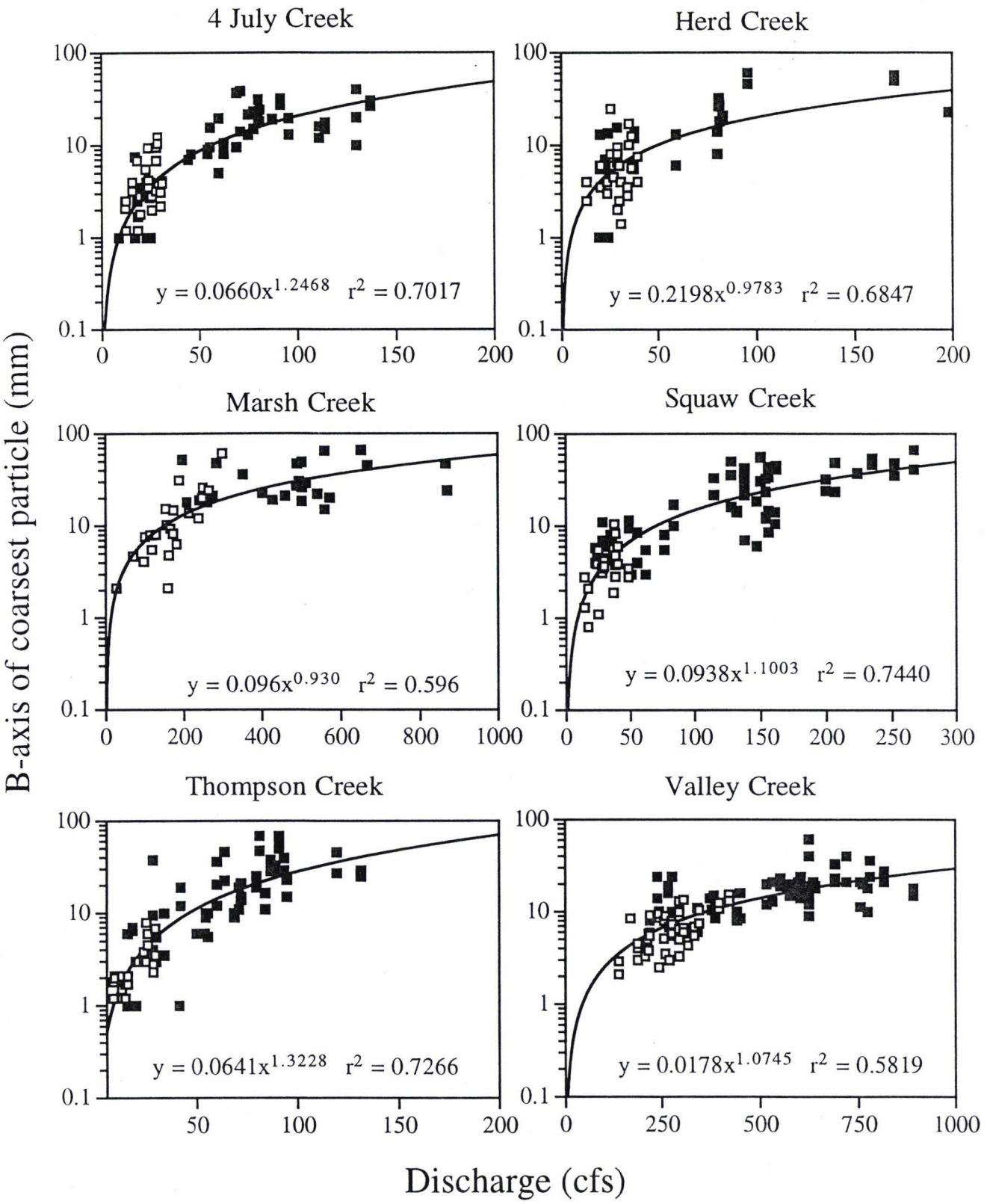

4 July Creek
y = 0.0660x^1.2468 r^2 = 0.7017
Herd Creek
y = 0.2198x^0.9783 r^2 = 0.6847
Marsh Creek
y = 0.096x^0.930 r^2 = 0.596
Squaw Creek
y = 0.0938x^1.1003 r^2 = 0.7440
Thompson Creek
y = 0.0641x^1.3228 r^2 = 0.7266
Valley Creek
y = 0.0178x^1.0745 r^2 = 0.5819
B-axis of coarsest particle (mm)
Discharge (cfs)

Figure 8

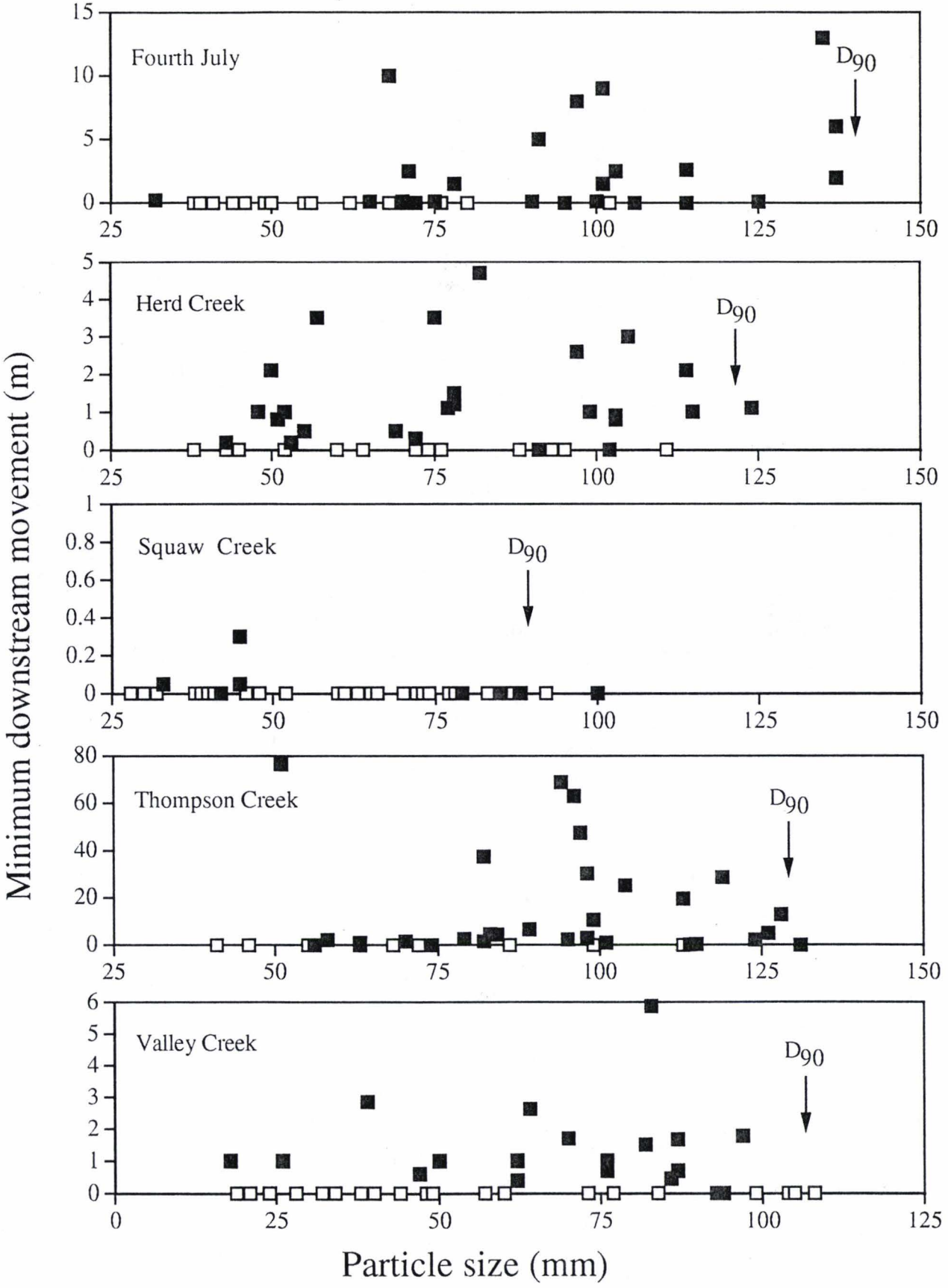

Minimum downstream movement (m)
Fourth July
D90
Herd Creek
D90
Squaw Creek
D90
Thompson Creek
D90
Valley Creek
D90
Particle size (mm)

Figure 9a

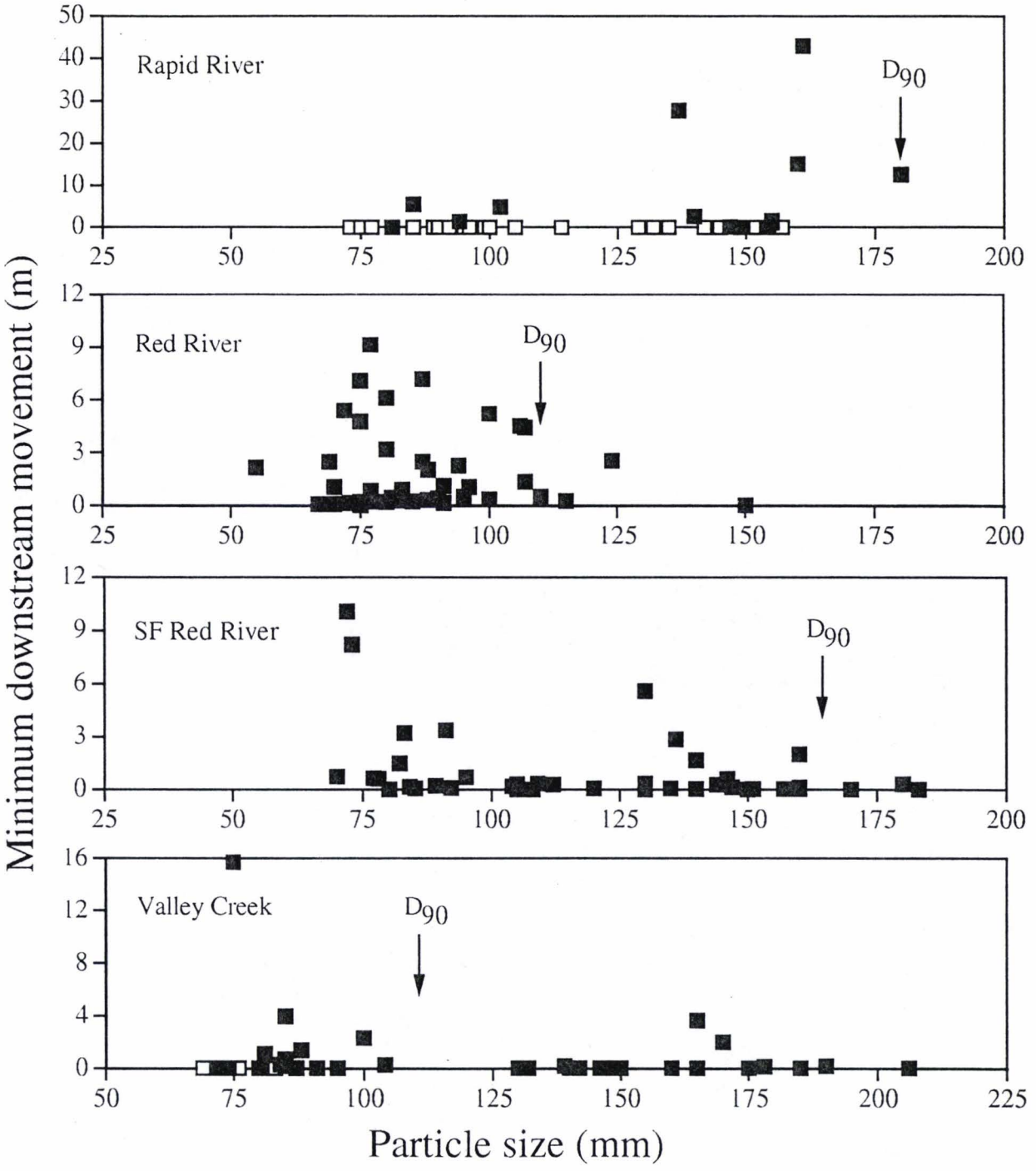

Minimum downstream movement (m)
Rapid River
D90
Red River
D90
SF Red River
D90
Valley Creek
D90
Particle size (mm)

Figure 9b

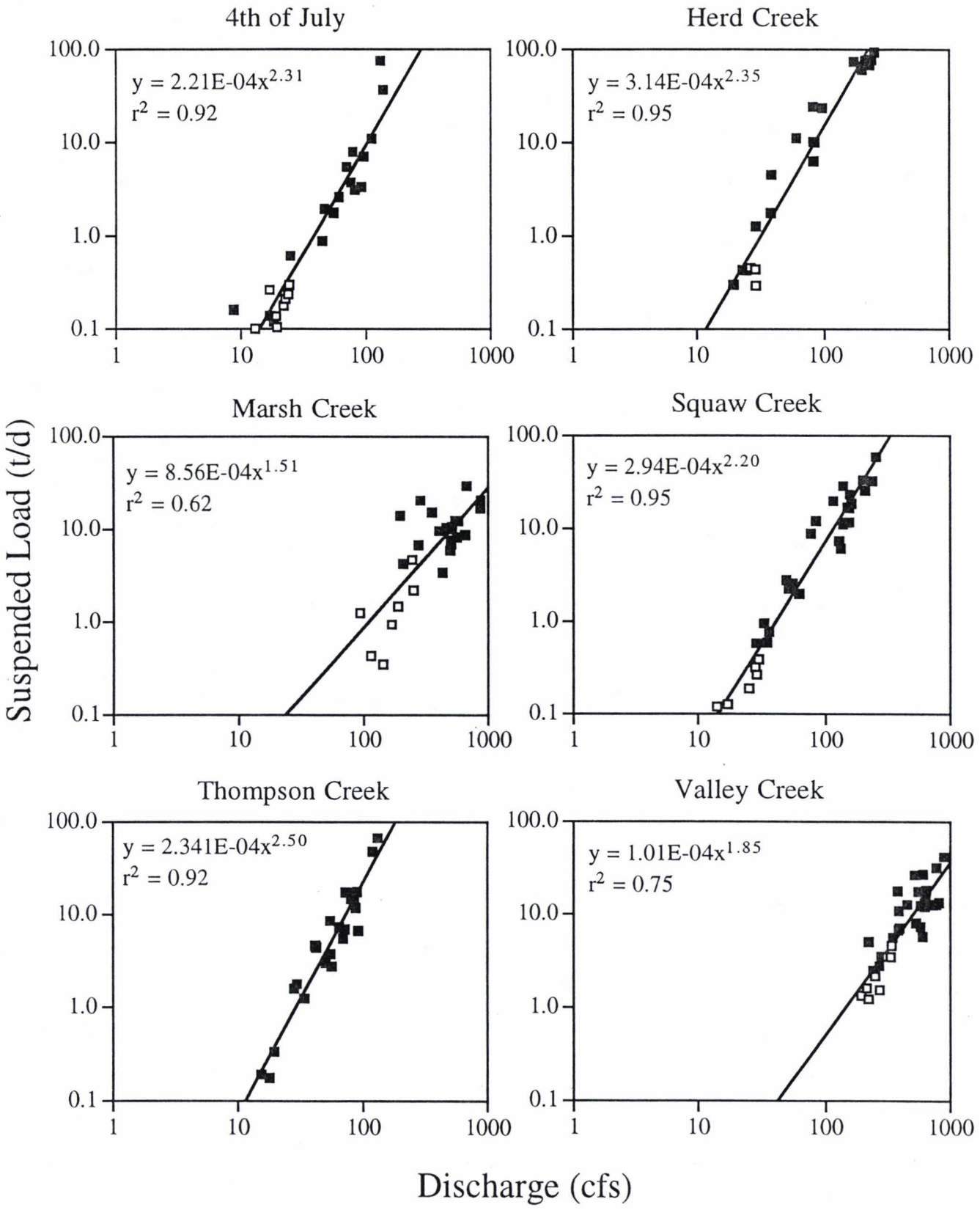

4th of July
y = 2.21E-04x^2.31
r^2 = 0.92
Herd Creek
y = 3.14E-04x^2.35
r^2 = 0.95
Marsh Creek
y = 8.56E-04x^1.51
r^2 = 0.62
Squaw Creek
y = 2.94E-04x^2.20
r^2 = 0.95
Thompson Creek
y = 2.341E-04x^2.50
r^2 = 0.92
Valley Creek
y = 1.01E-04x^1.85
r^2 = 0.75
Suspended Load (t/d)
Discharge (cfs)
100.0
10.0
1.0
0.1
1
10
100
1000

Figure 10

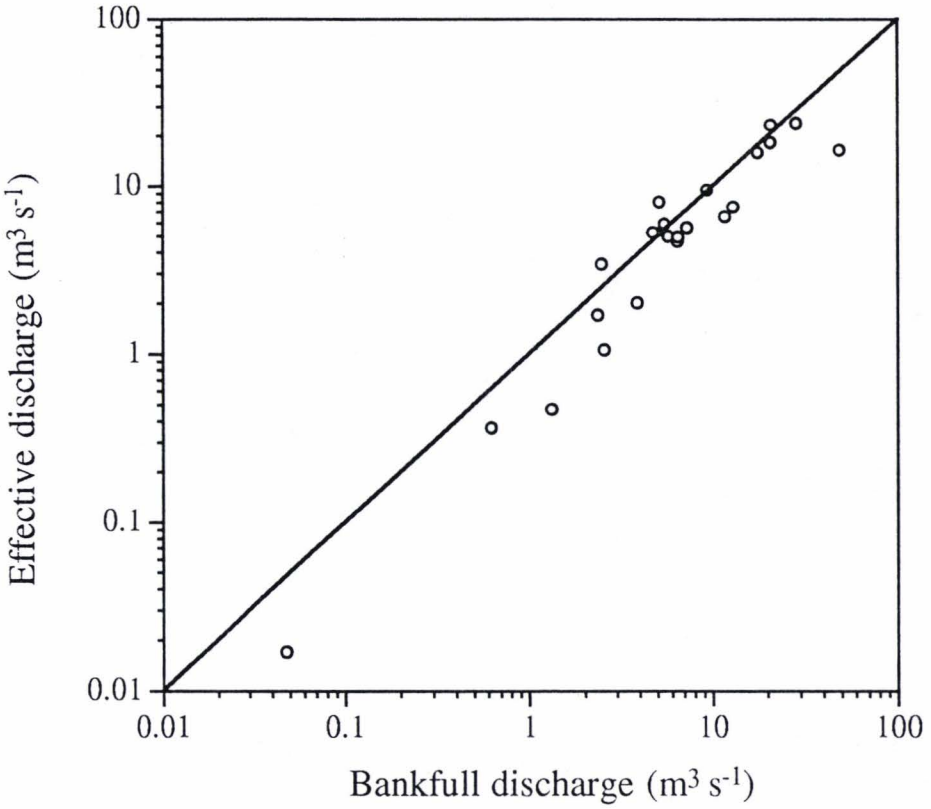

100
10
1
0.1
0.01
0.01
0.1
1
10
100
Effective discharge (m3 s-1)
Bankfull discharge (m3 s-1)

Figure 11

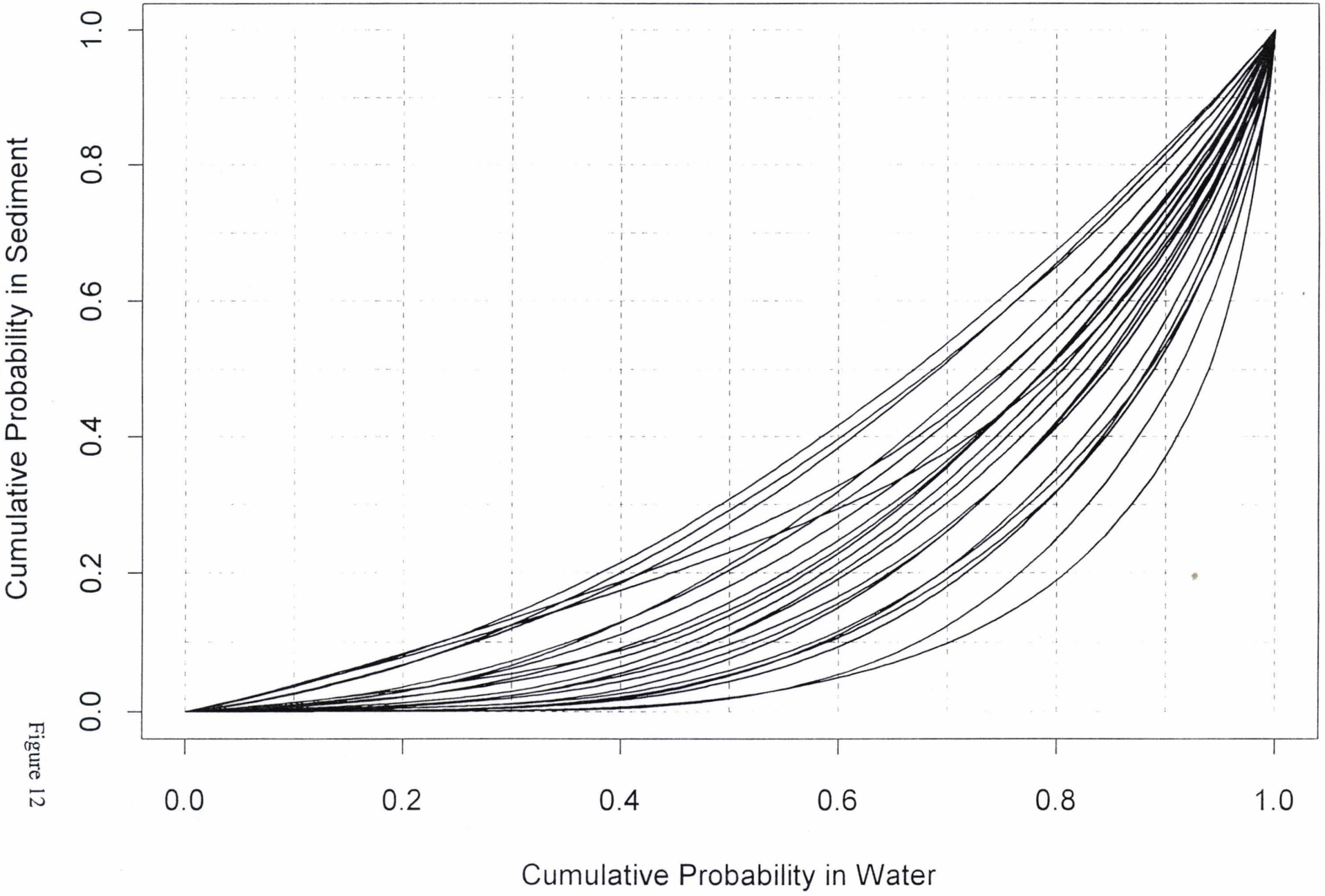

Efficiency Curves for 23 Idaho Streams
Cumulative Probability in Sediment
0.0
0.2
0.4
0.6
0.8
1.0
Cumulative Probability in Water
Wed Feb 12 11:54:00 1997

Figure 12

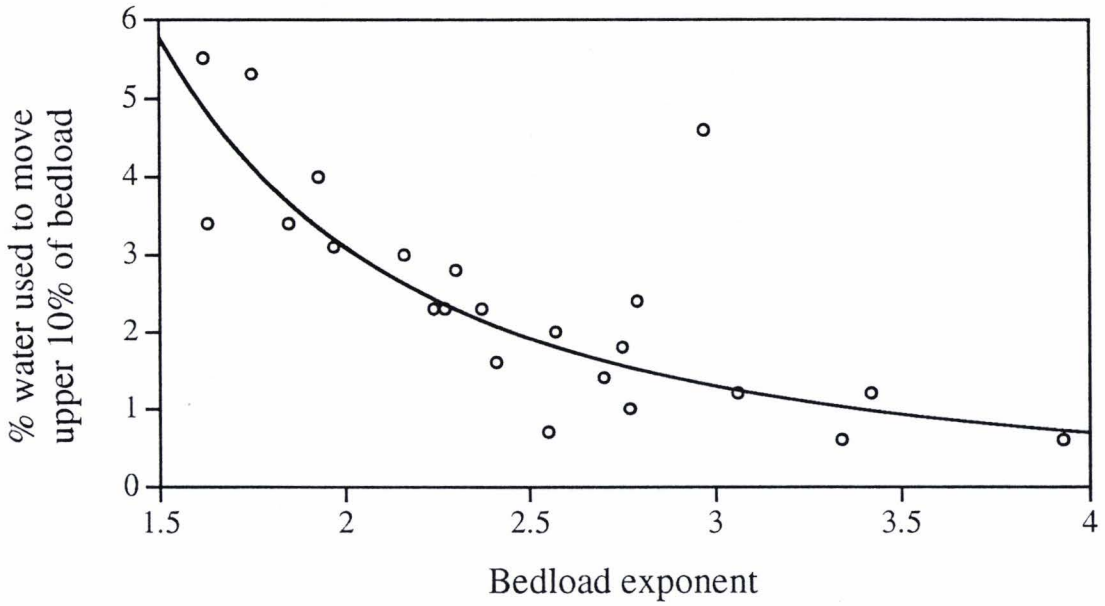

% water used to move upper 10% of bedload
6
5
4
3
2
1
0
1.5
2
2.5
3
3.5
4
Bedload exponent

Figure 13

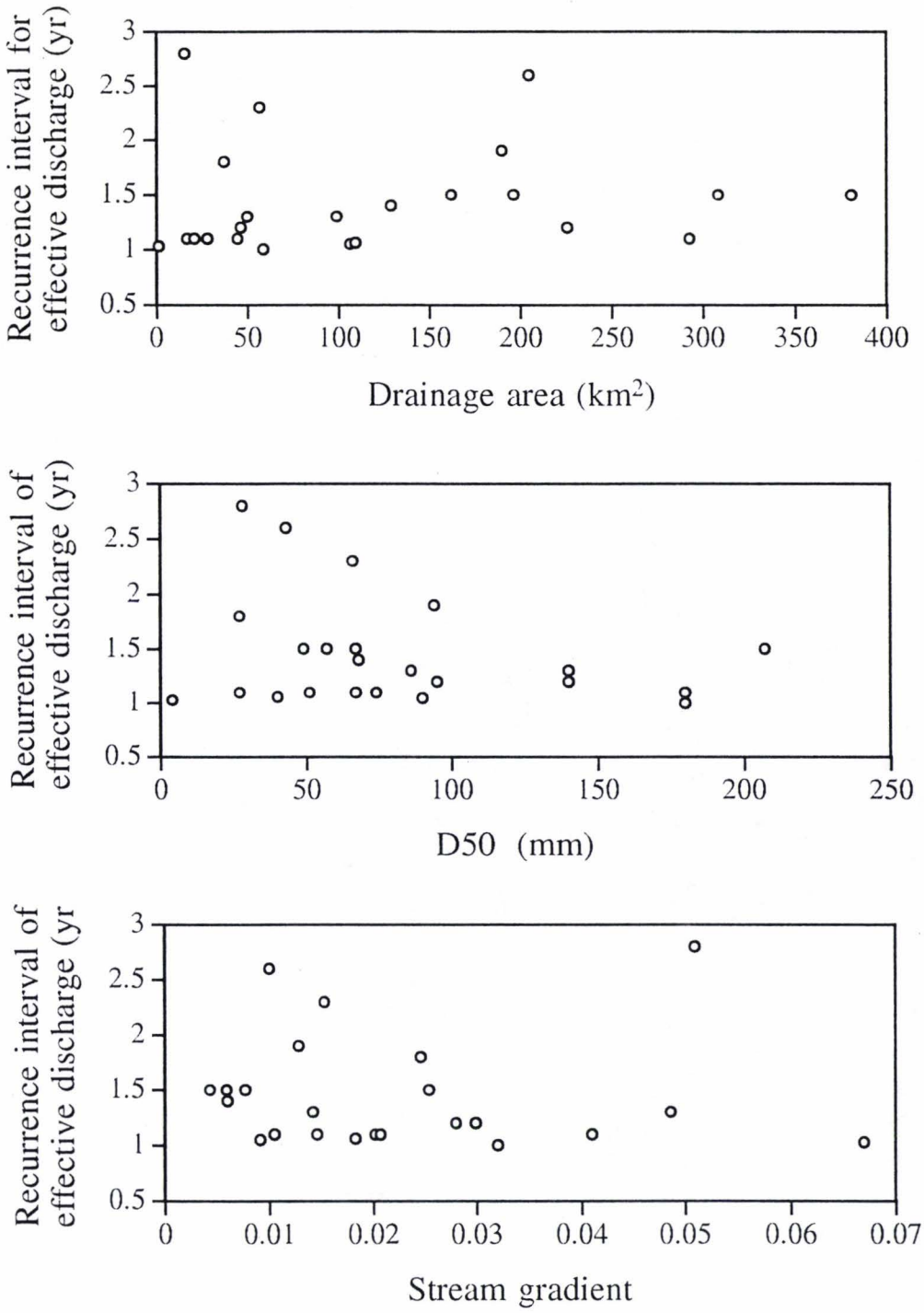

Recurrence interval for effective discharge (yr)
3
2.5
2
1.5
1
0.5
0
50
100
150
200
250
300
350
400
Drainage area (km2)
Recurrence interval of effective discharge (yr)
3
2.5
2
1.5
1
0.5
0
50
100
150
200
250
D50 (mm)
Recurrence interval of effective discharge (yr
3
2.5
2
1.5
1
0.5
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Stream gradient

Figure 14

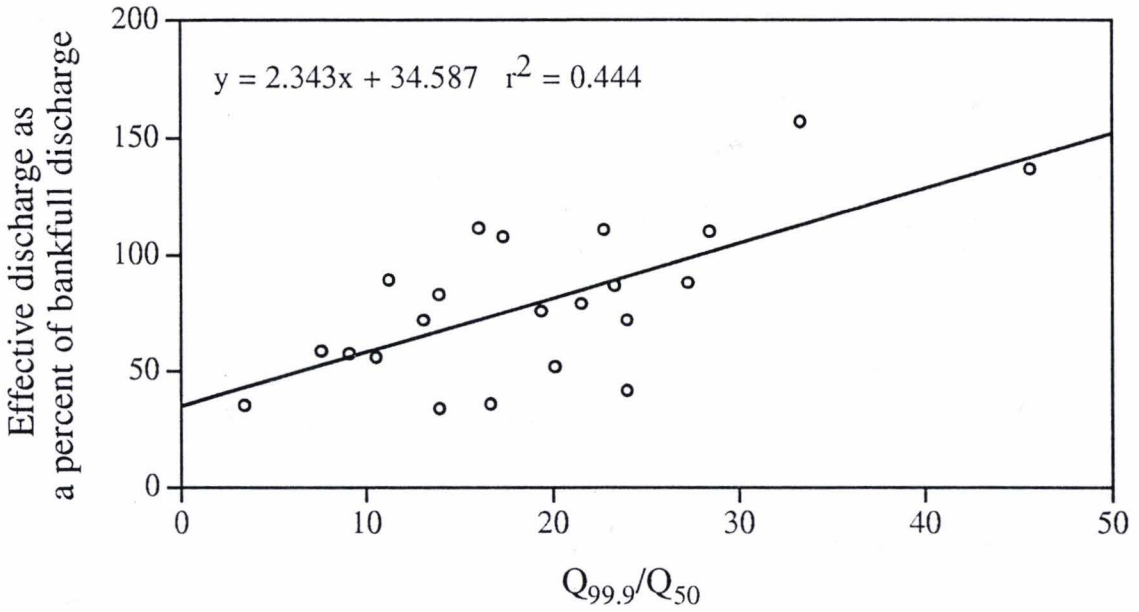

y = 2.343x + 34.587 r2 = 0.444
Effective discharge as a percent of bankfull discharge
200
150
100
50
0
0
10
20
30
40
50
Q99.9/Q50

Figure 15

APPENDICES to

Sediment transporting flows in headwater streams

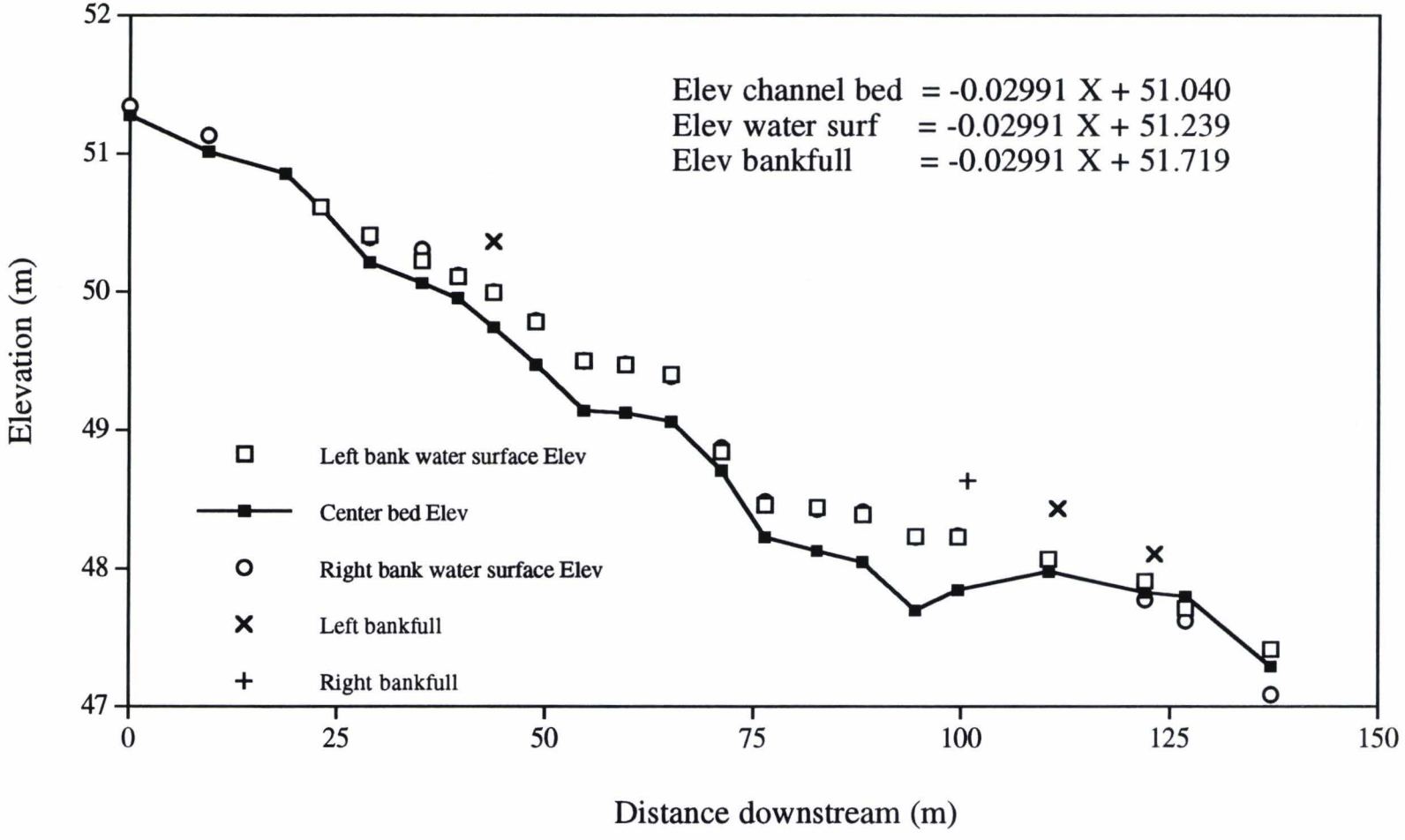
P.J. Whiting et al.

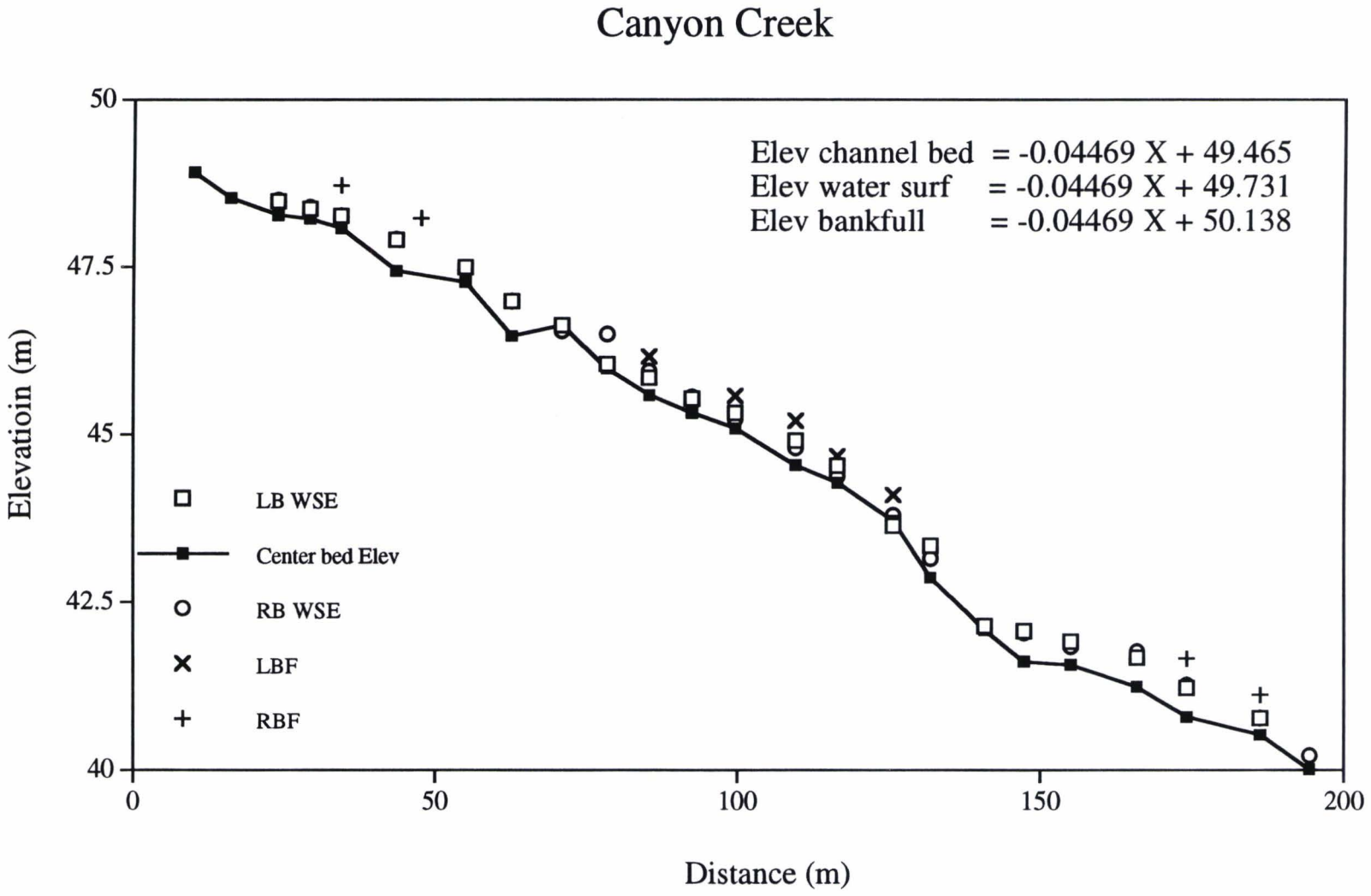
A report to the Intermountain Research Station, US Forest Service

Appendix A -

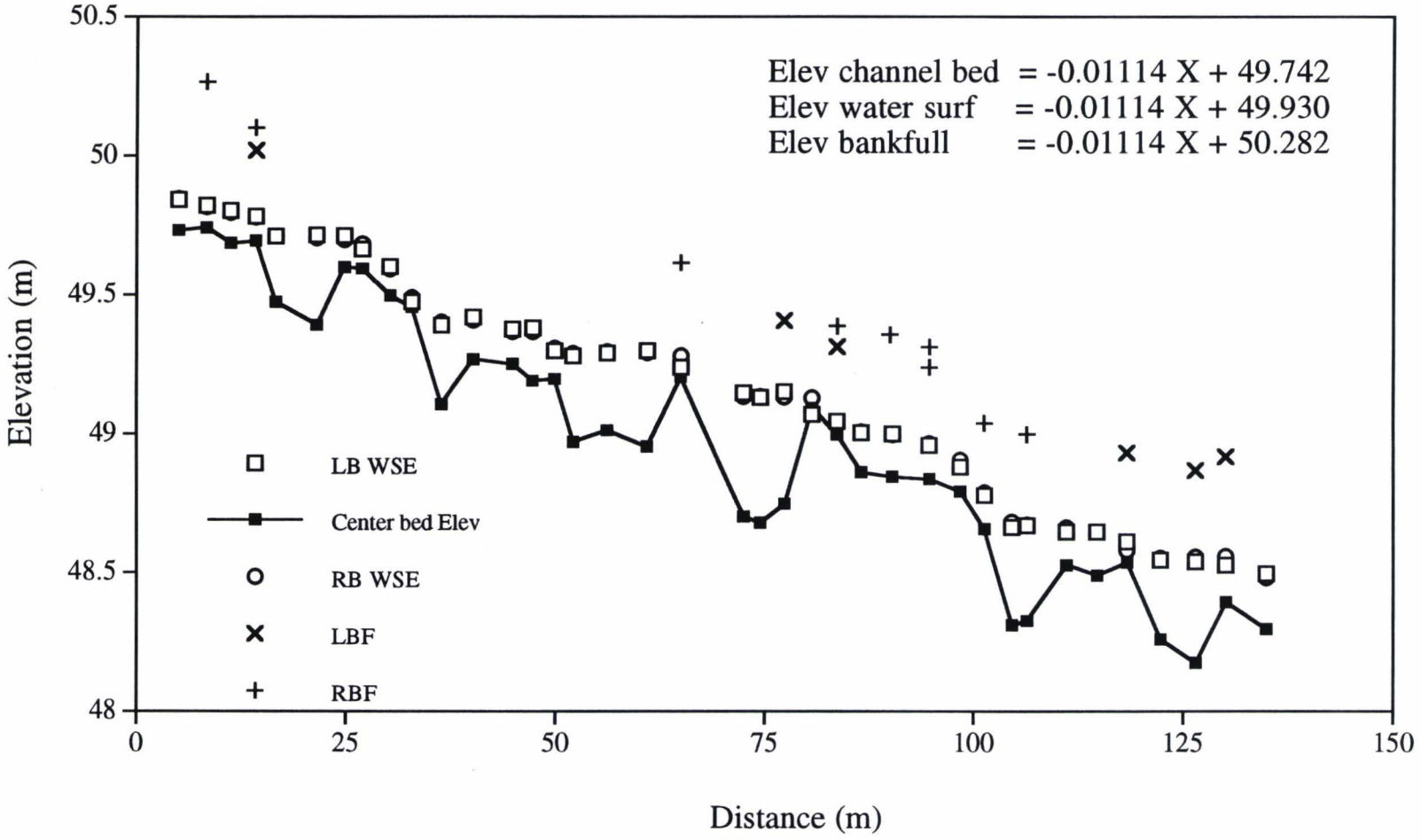
Maps, cross-sections, longitudinal profiles and surface particle analyses

Blackmare Creek

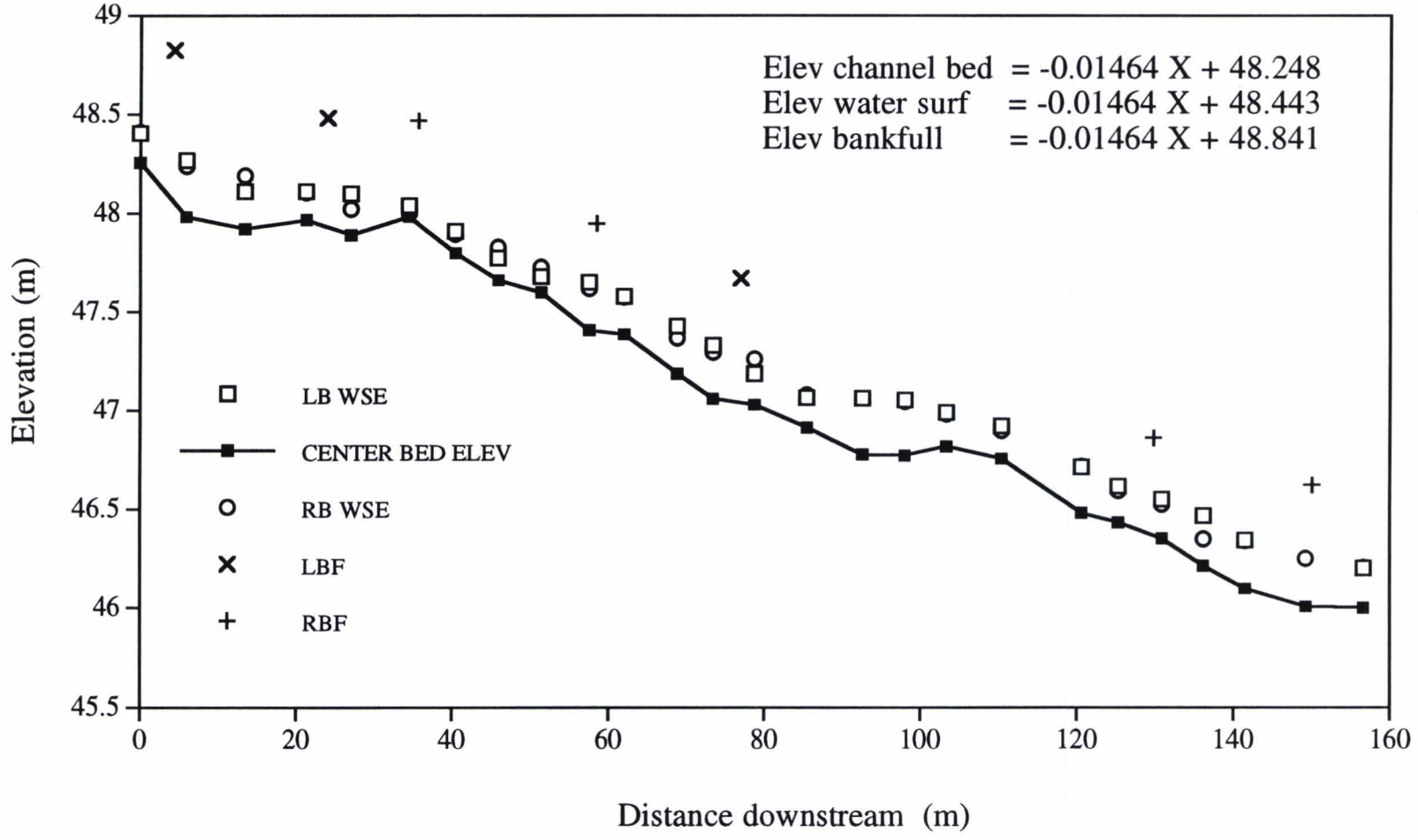



Canyon Creek
Elev channel bed = -0.04469 X + 49.465
Elev water surf = -0.04469 X + 49.731
Elev bankfull = -0.04469 X + 50.138
LB WSE
Center bed Elev
RB WSE
LBF
RBF
Elevatioin (m)
Distance (m)
50
47.5
45
42.5
40
0
50
100
150
200

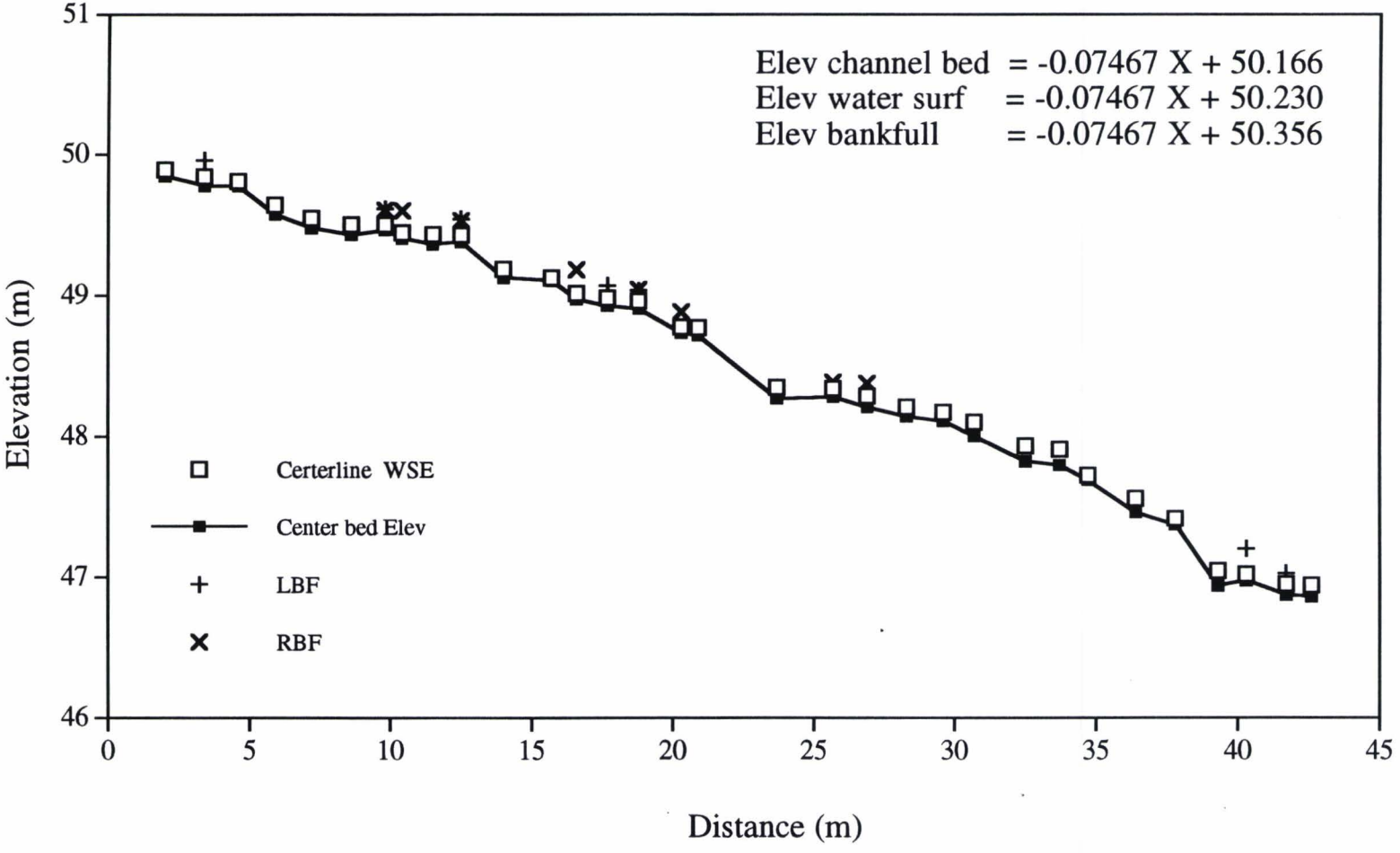
Catspur Creek

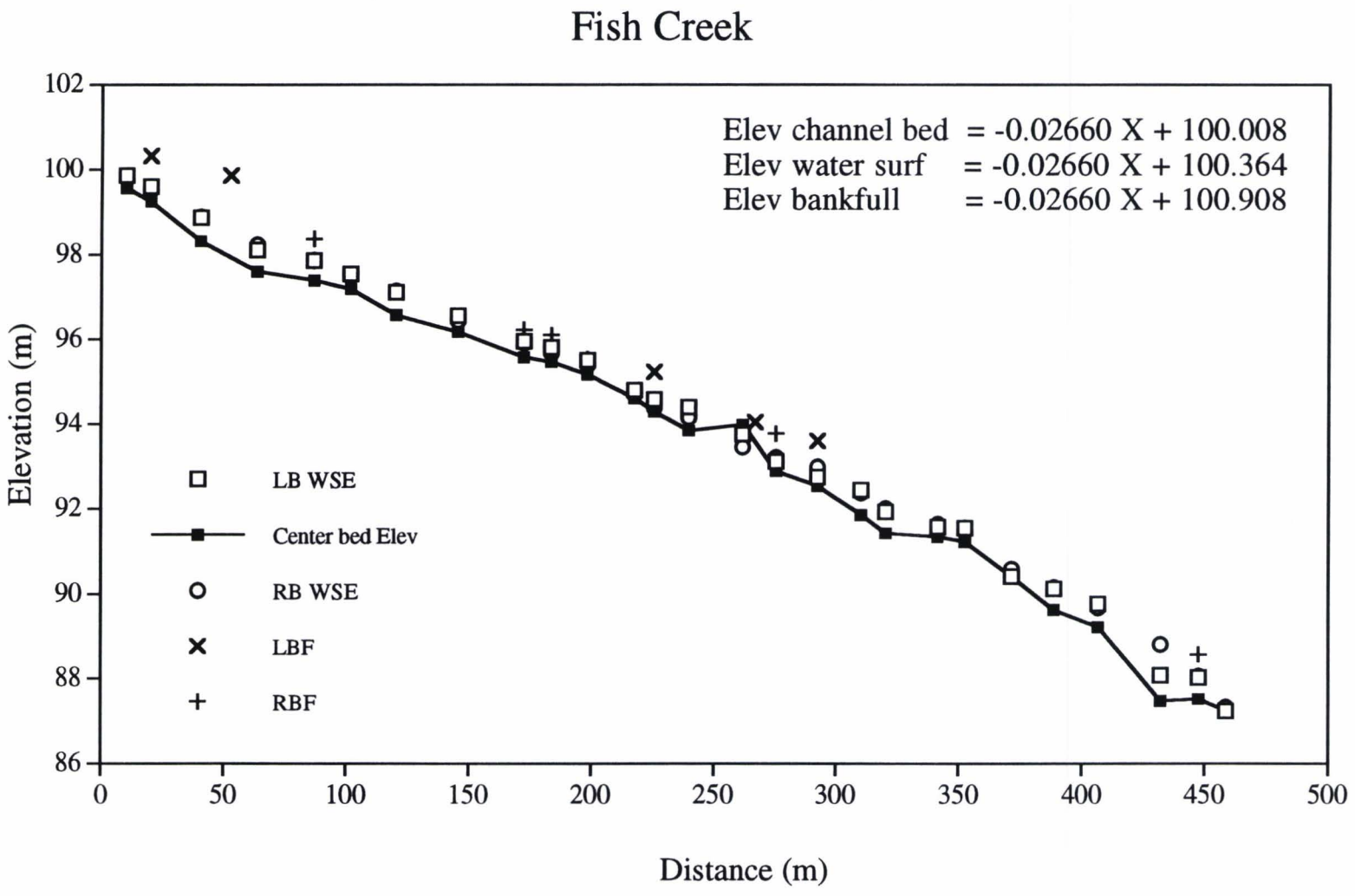


Dollar Creek

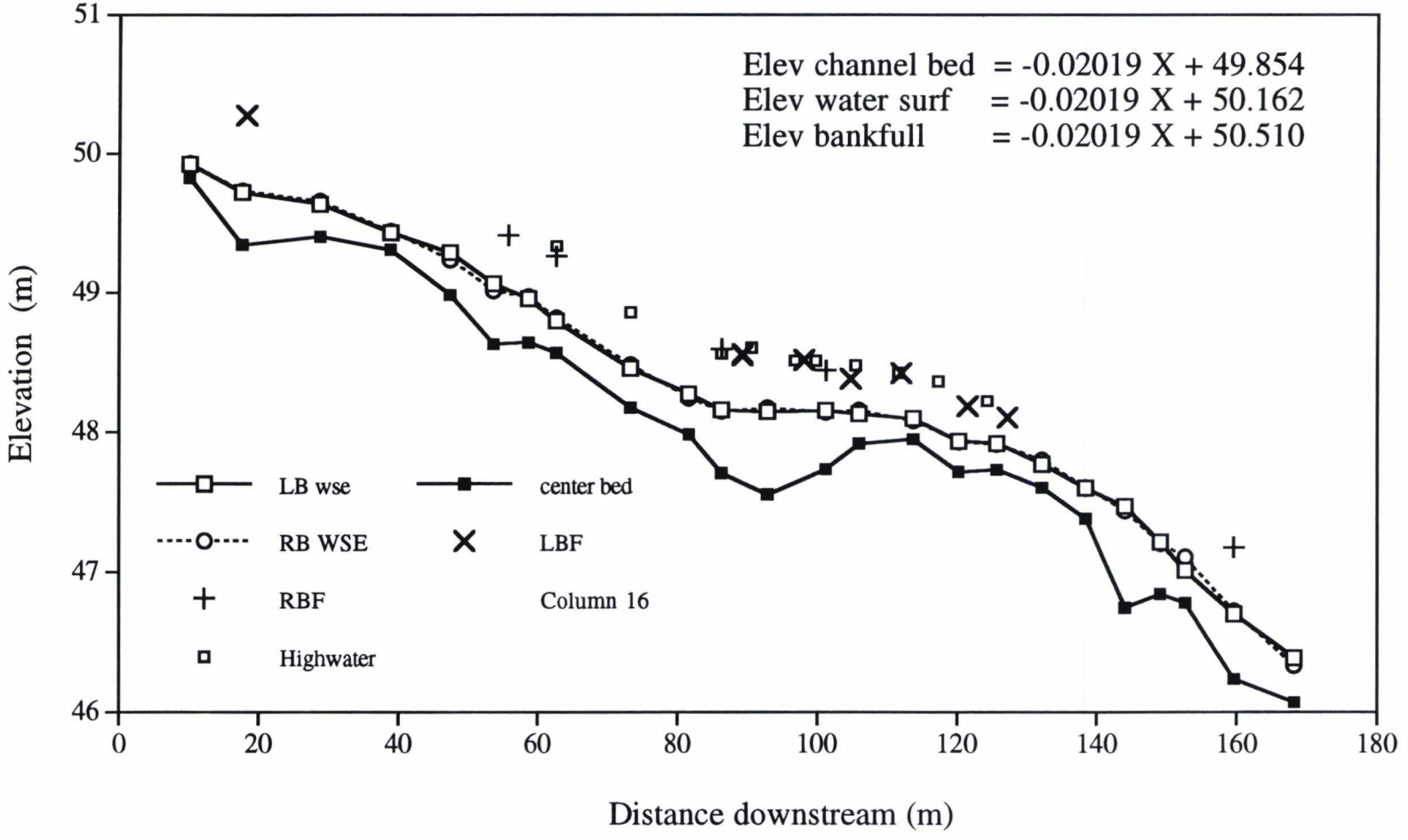


Eggers Creek

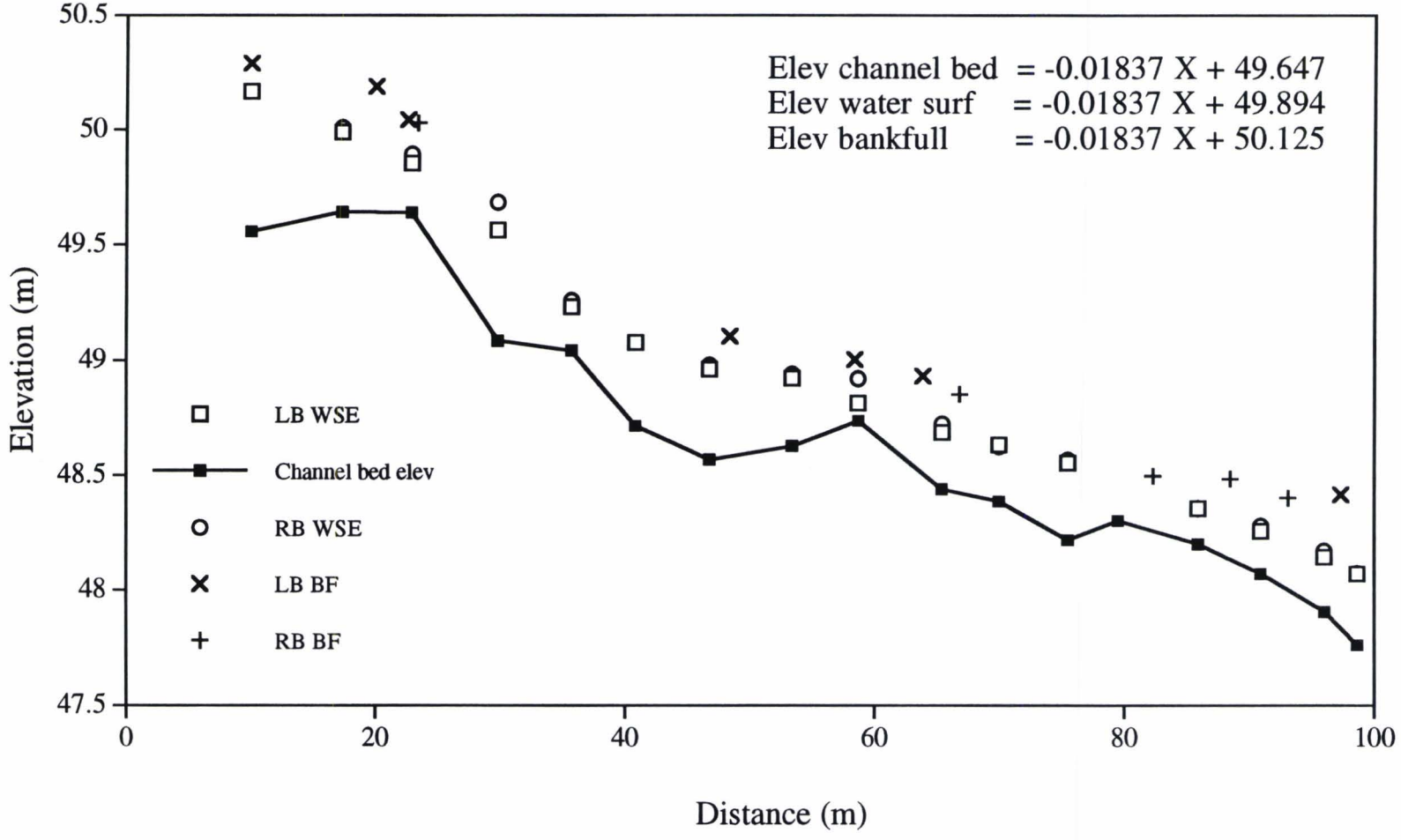


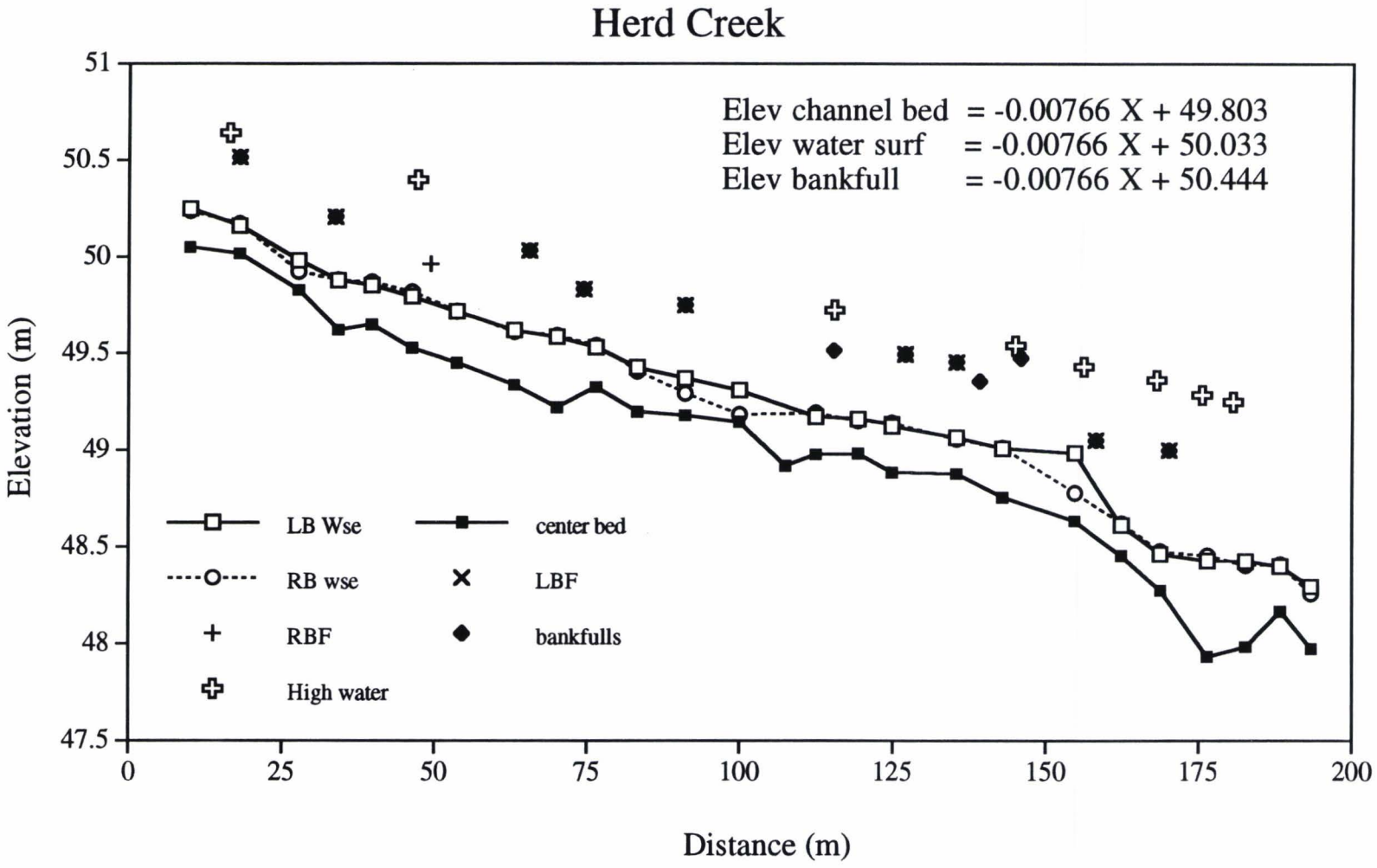

Fish Creek
Elev channel bed = -0.02660 X + 100.008
Elev water surf = -0.02660 X + 100.364
Elev bankfull = -0.02660 X + 100.908
LB WSE
Center bed Elev
RB WSE
LBF
RBF
Elevation (m)
Distance (m)
102
100
98
96
94
92
90
88
86
0
50
100
150
200
250
300
350
400
450
500

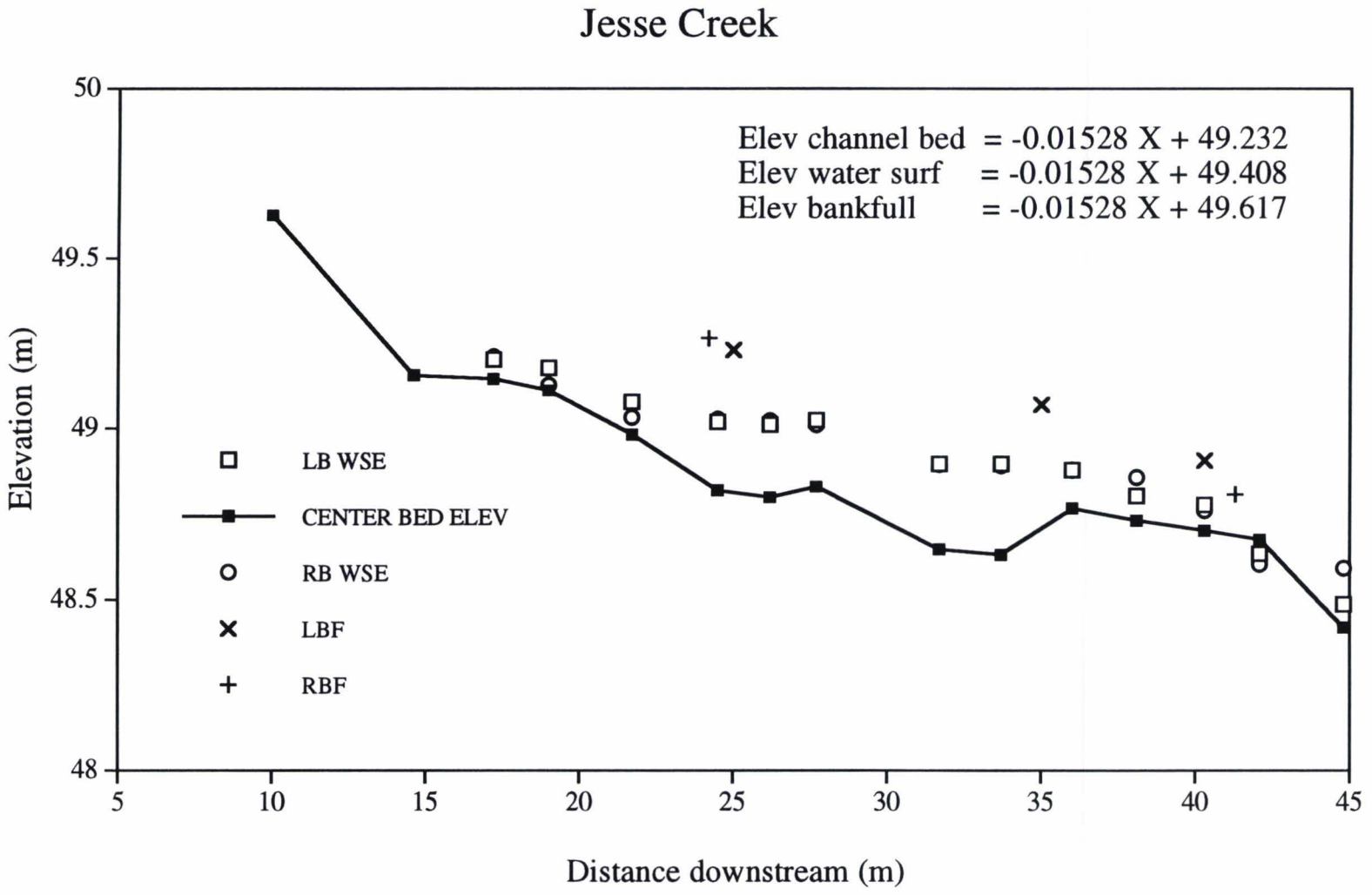
4th July Creek



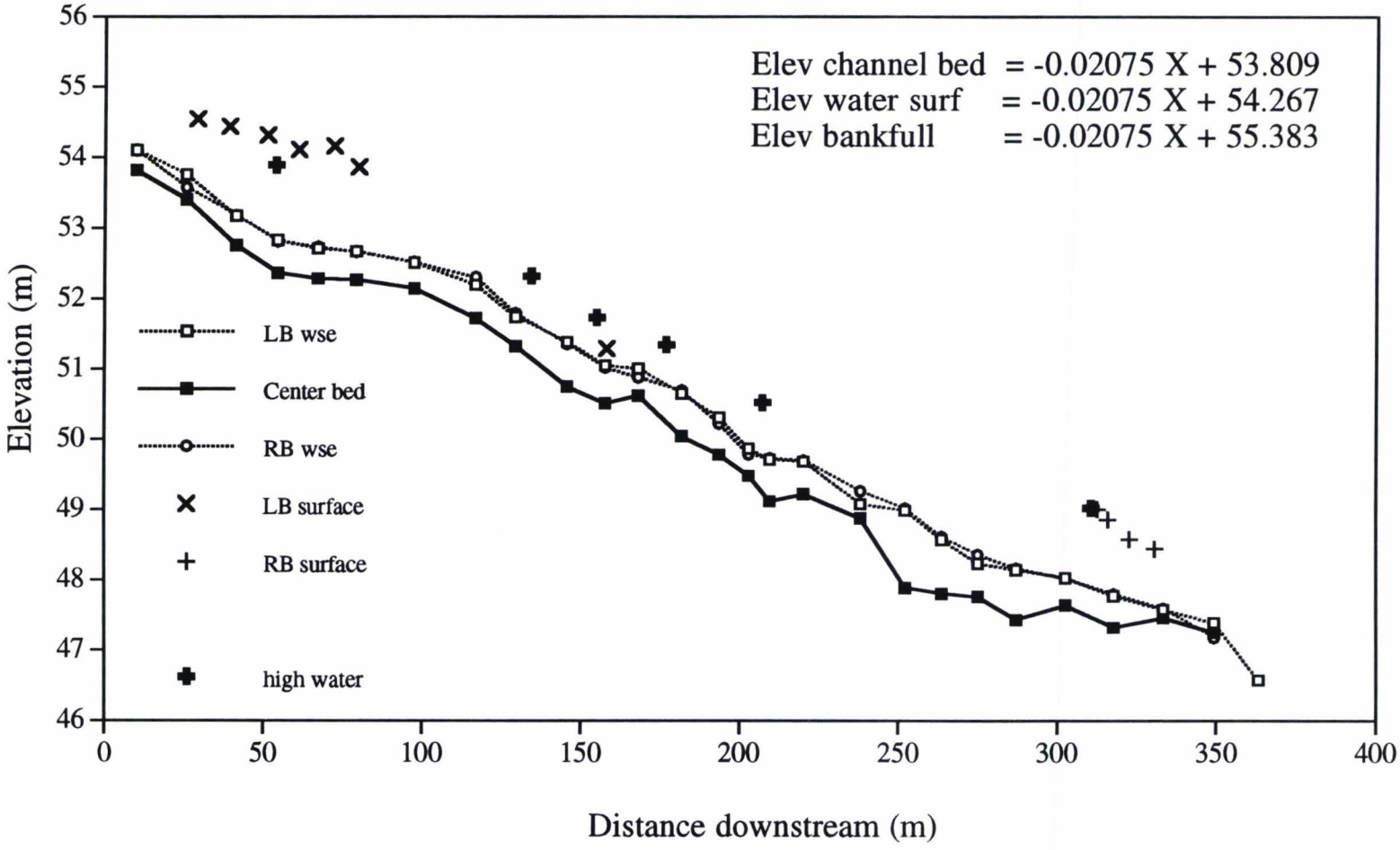
Hawley Creek



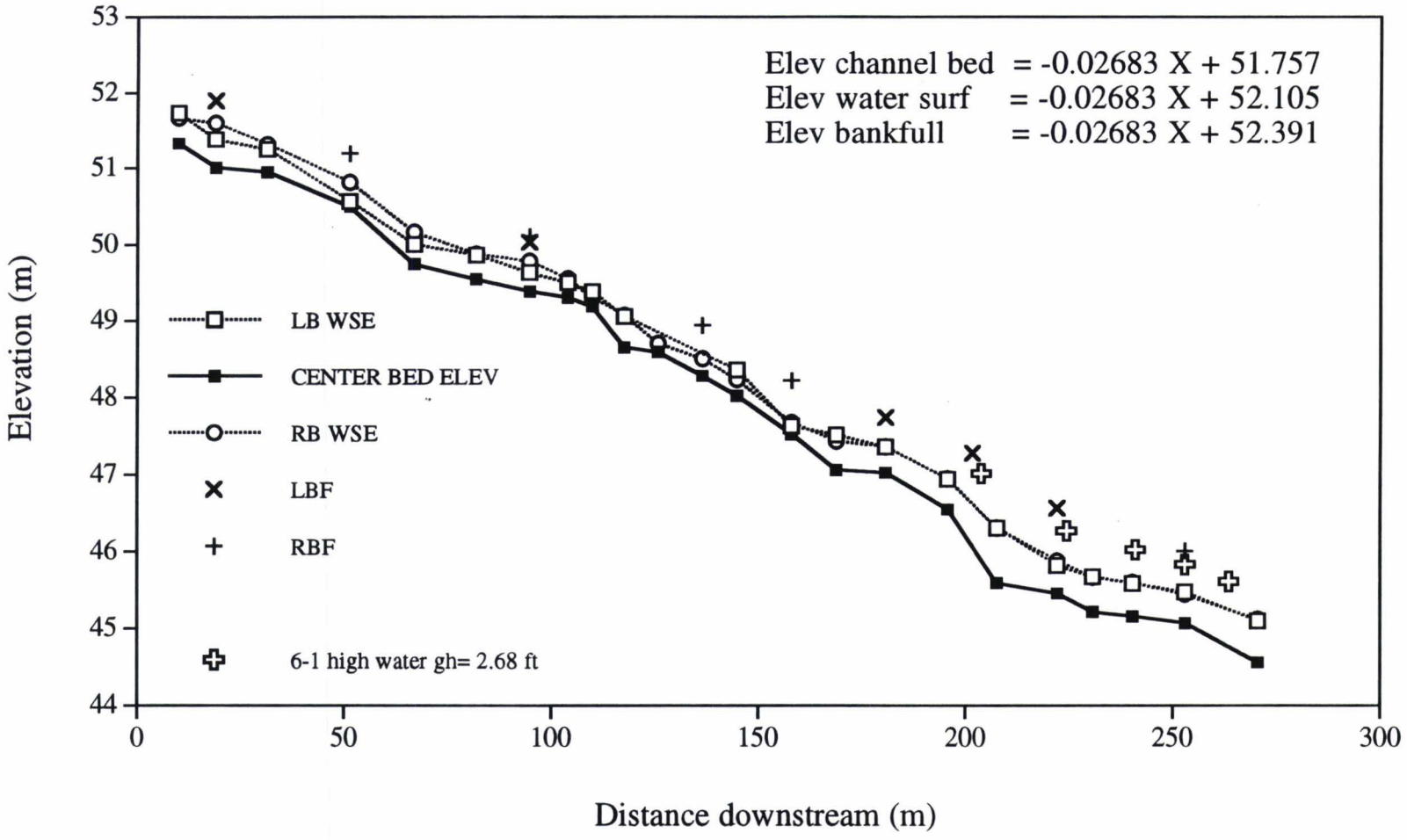

Herd Creek
Elev channel bed = -0.00766 X + 49.803
Elev water surf = -0.00766 X + 50.033
Elev bankfull = -0.00766 X + 50.444
LB Wse
center bed
RB wse
LBF
RBF
bankfulls
High water
Elevation (m)
Distance (m)
51
50.5
50
49.5
49
48.5
48
47.5
0
25
50
75
100
125
150
175
200


Jesse Creek
Elev channel bed = -0.01528 X + 49.232
Elev water surf = -0.01528 X + 49.408
Elev bankfull = -0.01528 X + 49.617
LB WSE
CENTER BED ELEV
RB WSE
LBF
RBF
Elevation (m)
Distance downstream (m)
50
49.5
49
48.5
48
5
10
15
20
25
30
35
40
45

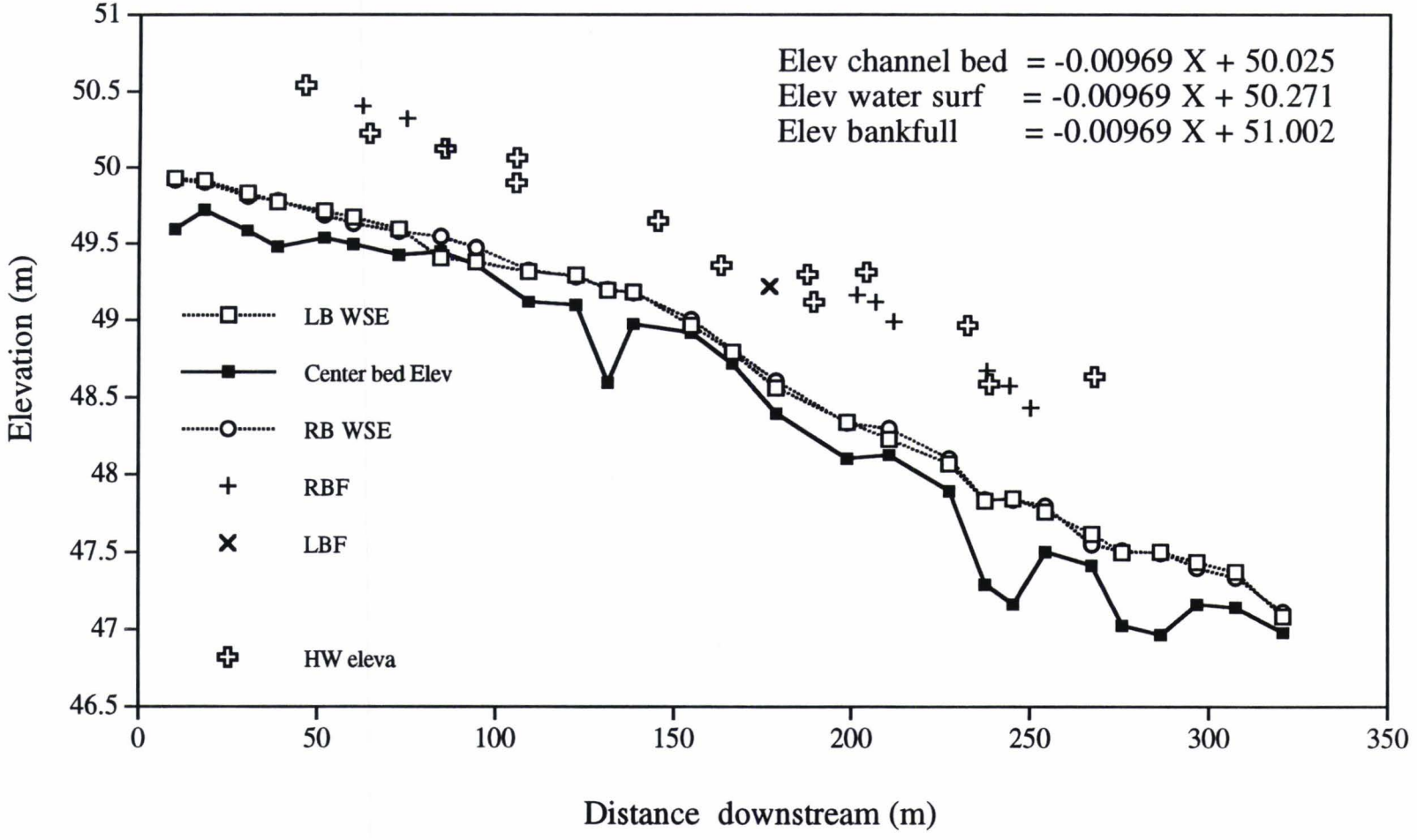
Johns Creek

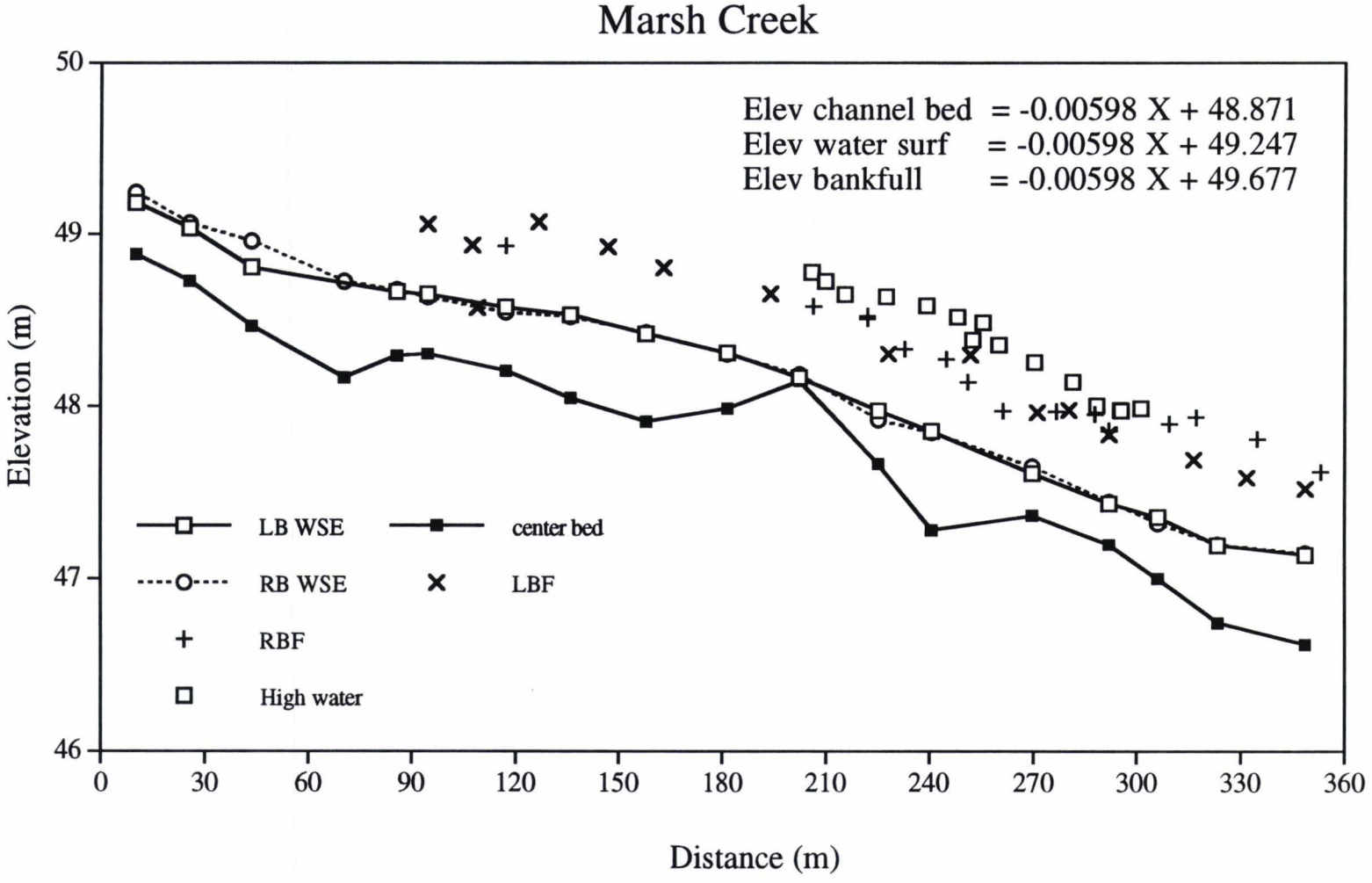

Elev channel bed = -0.02075 X + 53.809
Elev water surf = -0.02075 X + 54.267
Elev bankfull = -0.02075 X + 55.383
LB wse
Center bed
RB wse
LB surface
RB surface
high water
Elevation (m)
Distance downstream (m)
56
55
54
53
52
51
50
49
48
47
46
0
50
100
150
200
250
300
350
400

Little Slate Creek

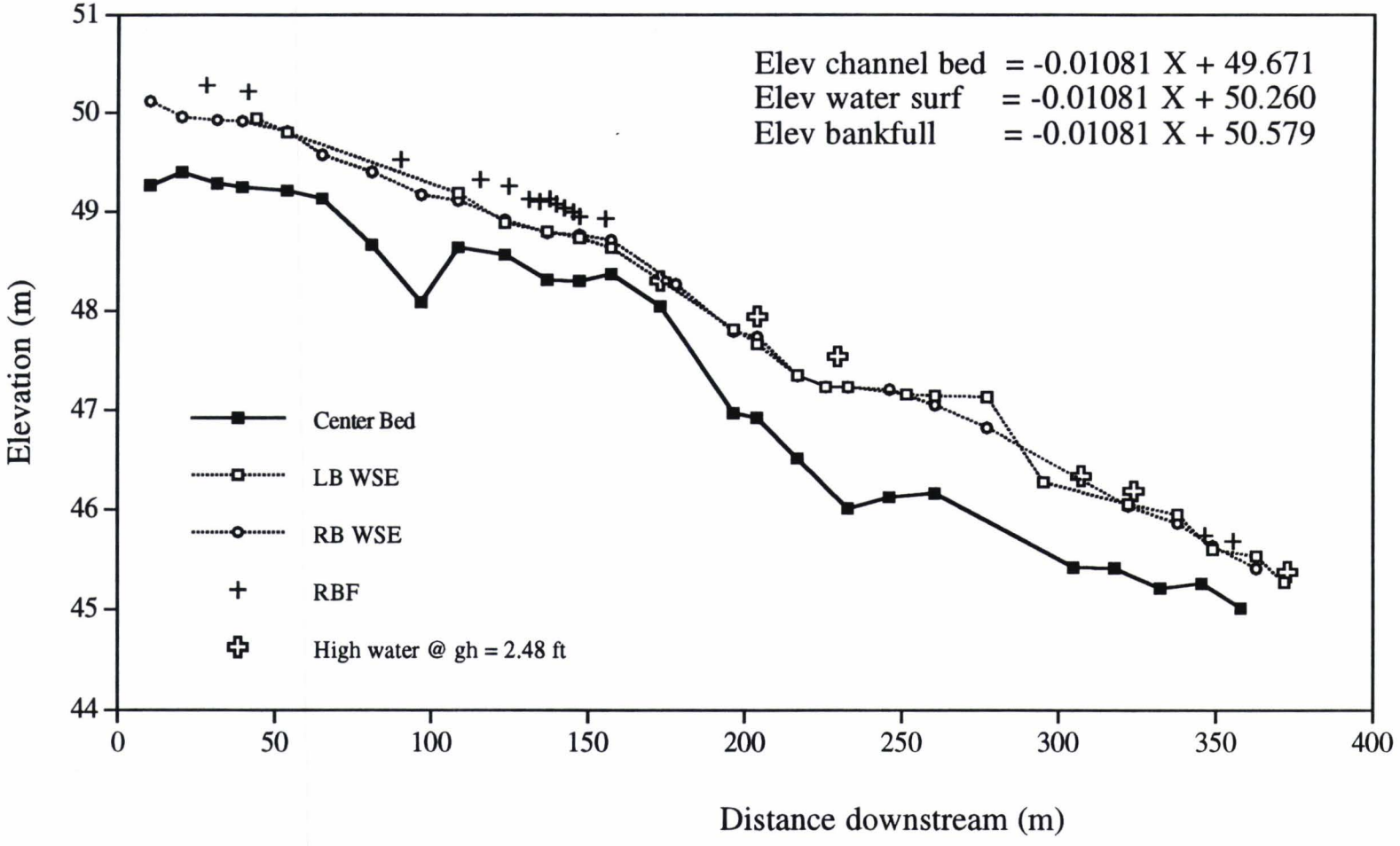


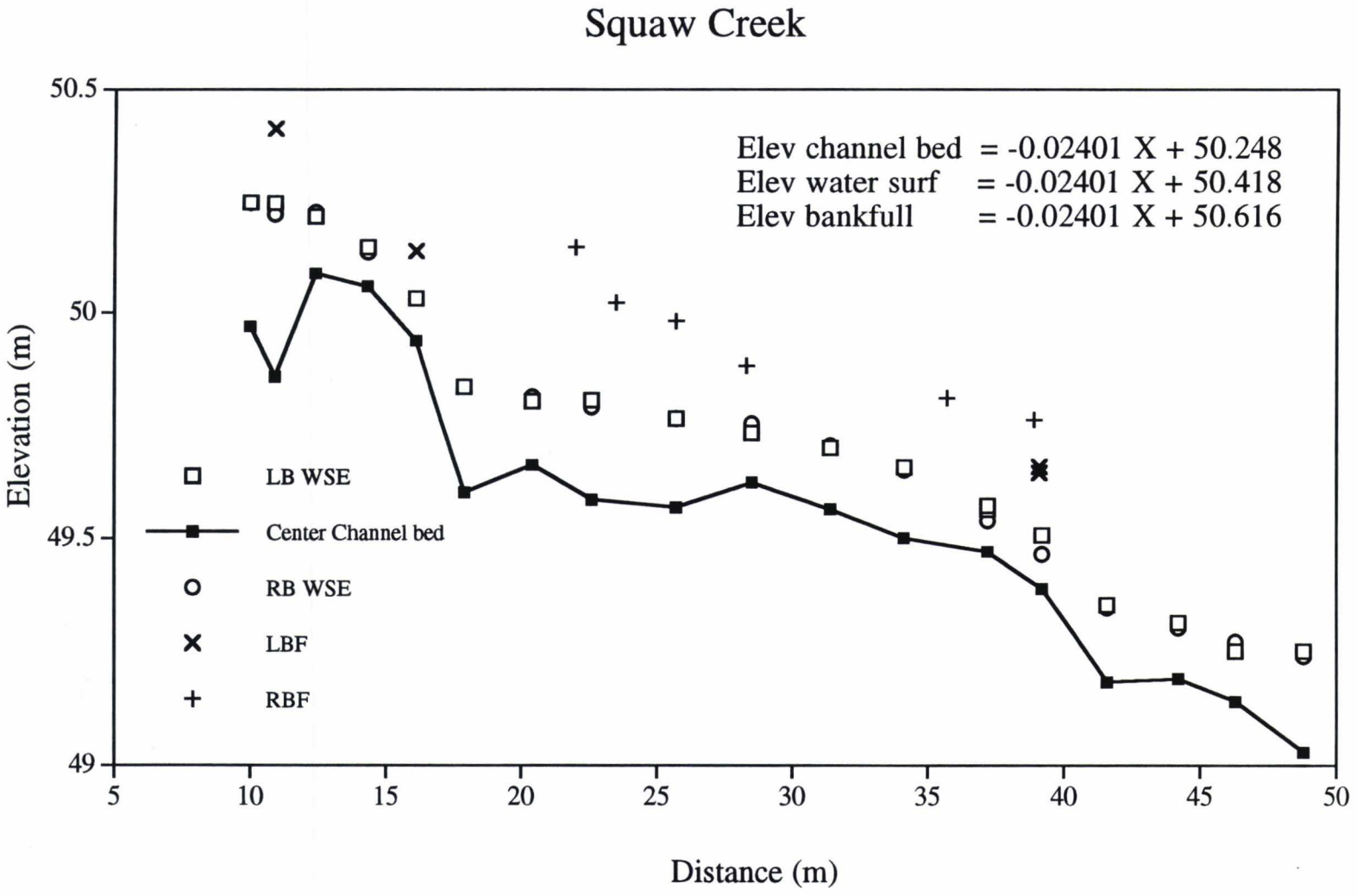
Lolo Creek


Elev channel bed = -0.00969 X + 50.025
Elev water surf = -0.00969 X + 50.271
Elev bankfull = -0.00969 X + 51.002
LB WSE
Center bed Elev
RB WSE
RBF
LBF
HW eleva
Elevation (m)
Distance downstream (m)
51
50.5
50
49.5
49
48.5
48
47.5
47
46.5
0
50
100
150
200
250
300
350

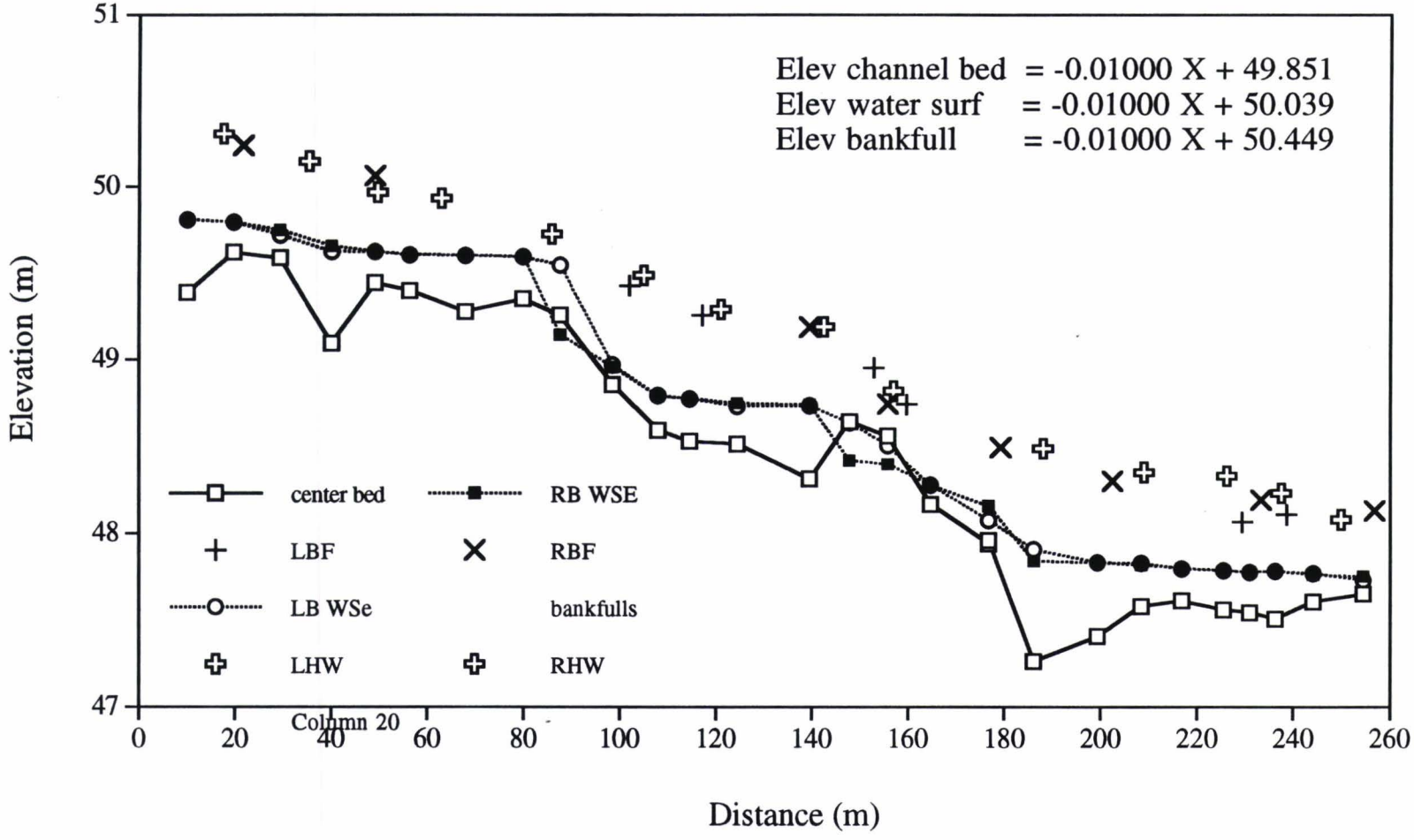

Marsh Creek
Elev channel bed = -0.00598 X + 48.871
Elev water surf = -0.00598 X + 49.247
Elev bankfull = -0.00598 X + 49.677
LB WSE
center bed
RB WSE
LBF
RBF
High water
Elevation (m)
Distance (m)
50
49
48
47
46
0
30
60
90
120
150
180
210
240
270
300
330
360

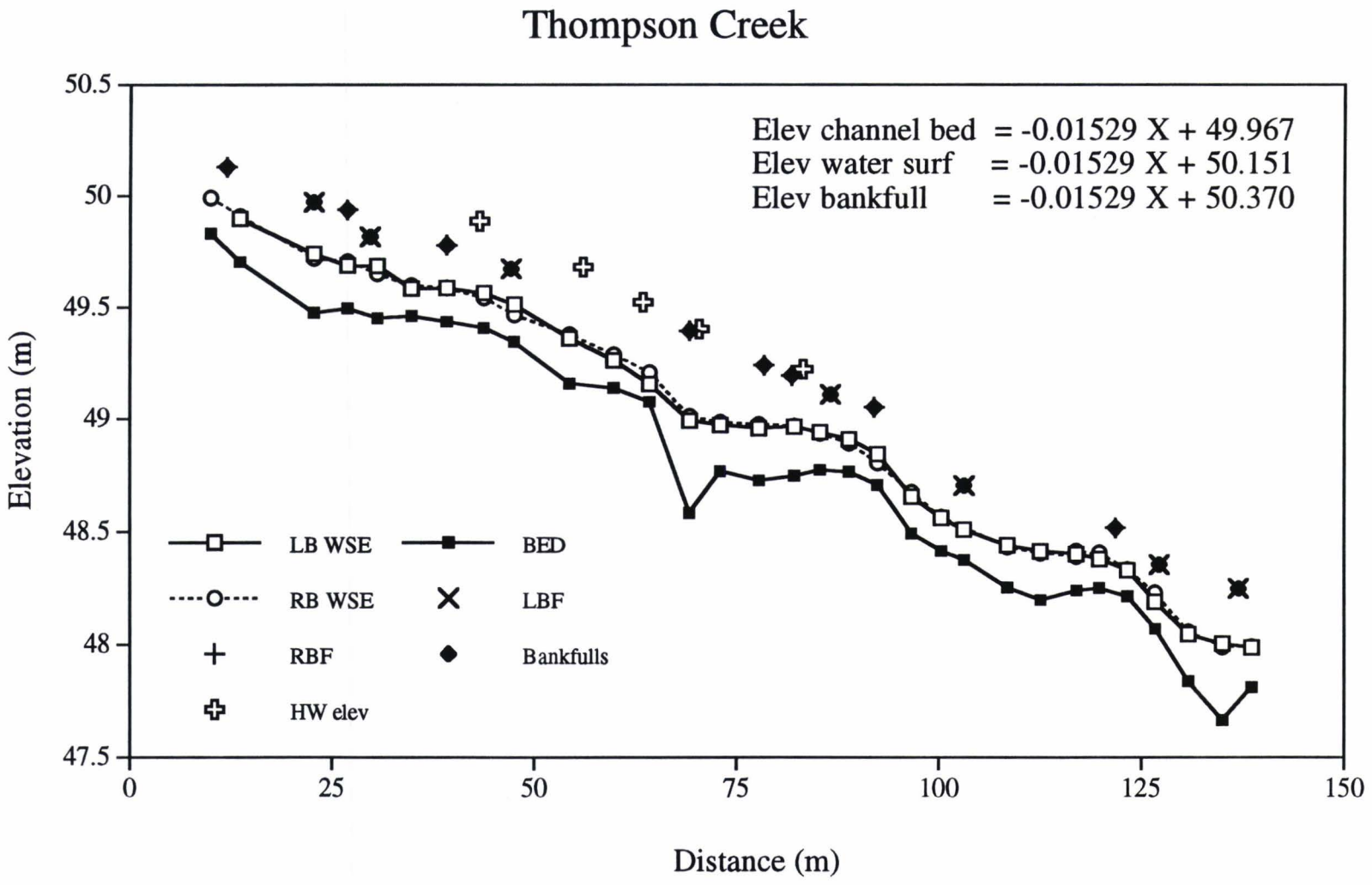
Rapid River 1995

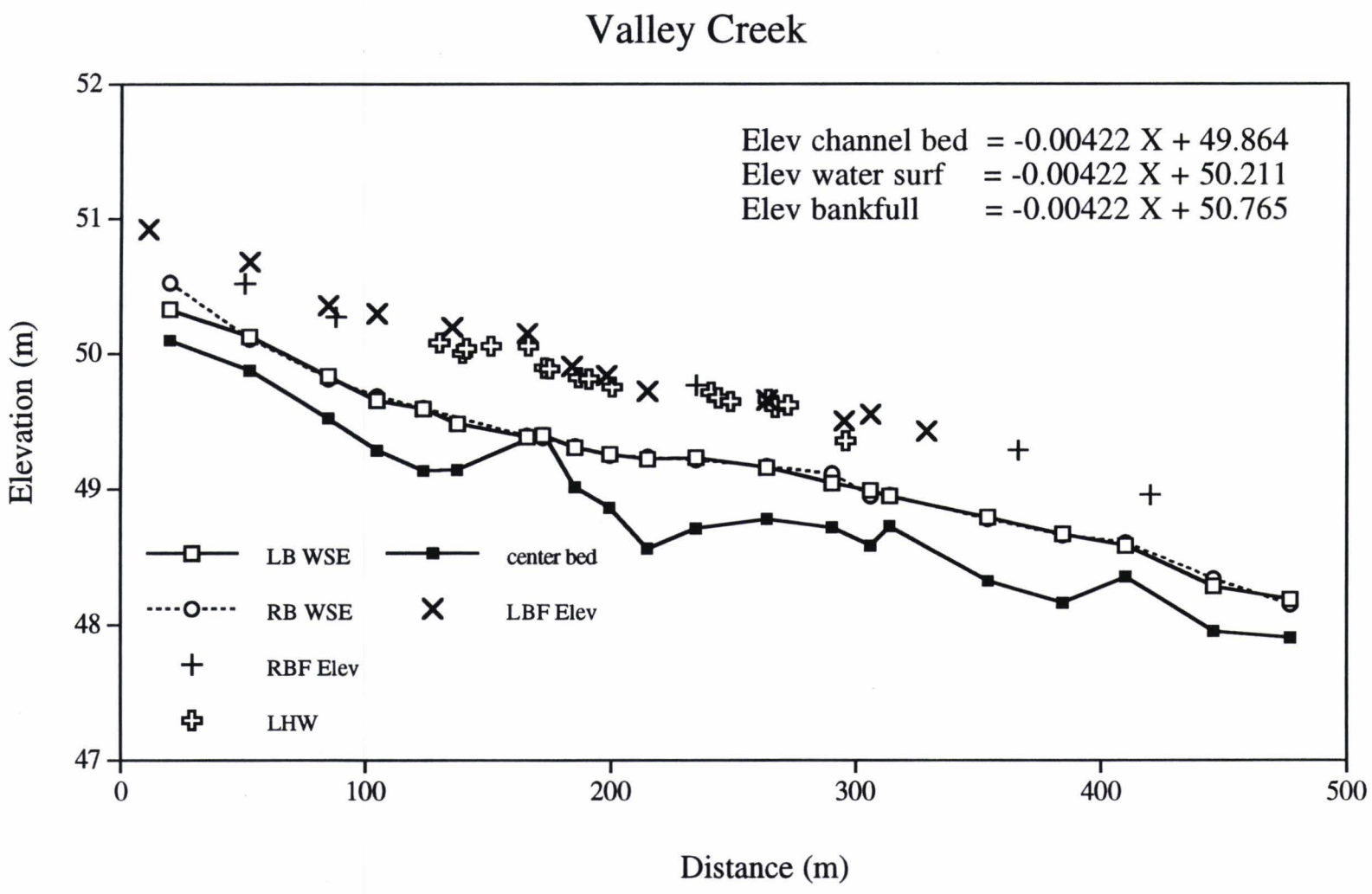



Squaw Creek
Elev channel bed = -0.02401 X + 50.248
Elev water surf = -0.02401 X + 50.418
Elev bankfull = -0.02401 X + 50.616
LB WSE
Center Channel bed
RB WSE
LBF
RBF
Elevation (m)
Distance (m)
50.5
50
49.5
49
5
10
15
20
25
30
35
40
45
50

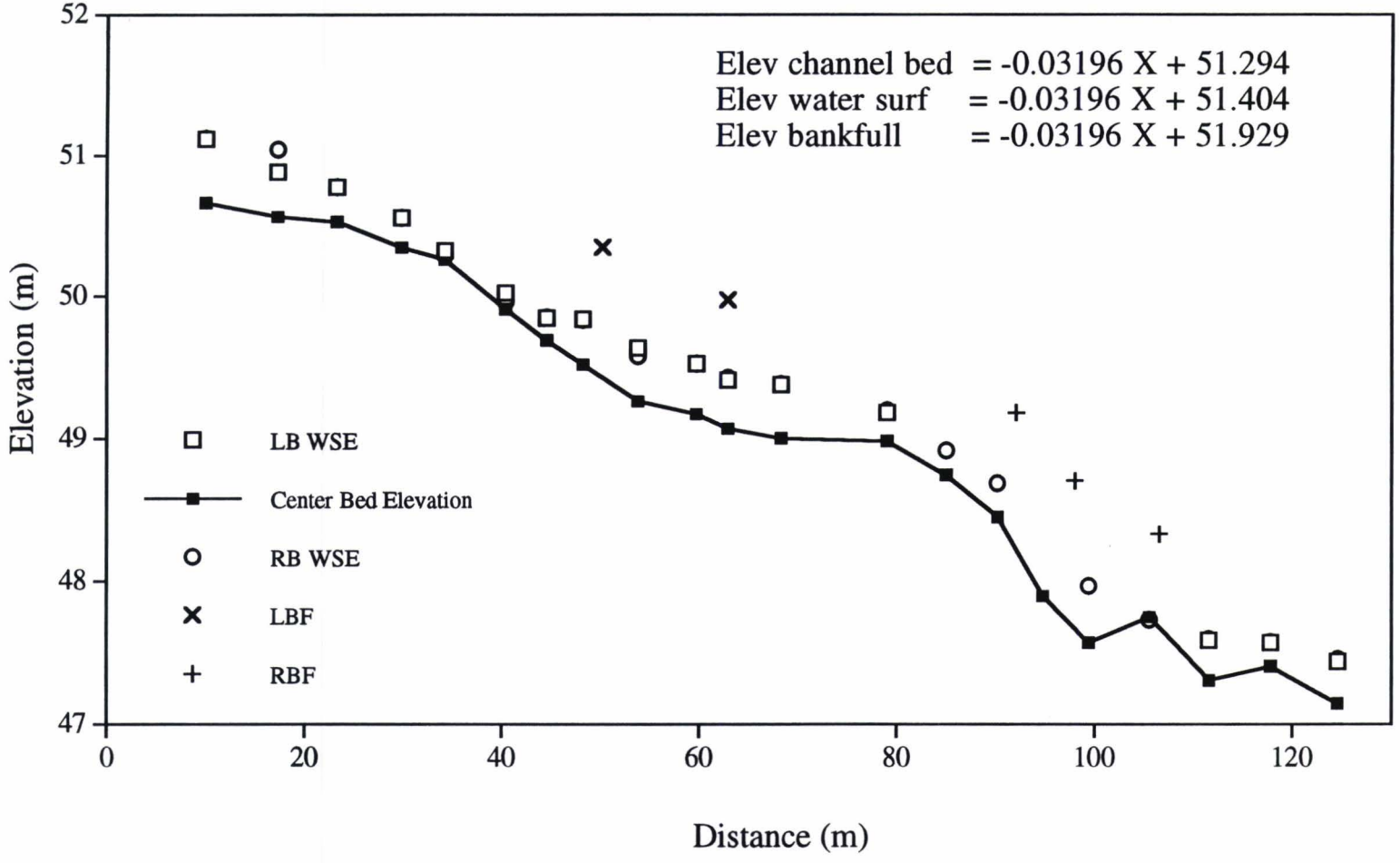
Squaw Creek

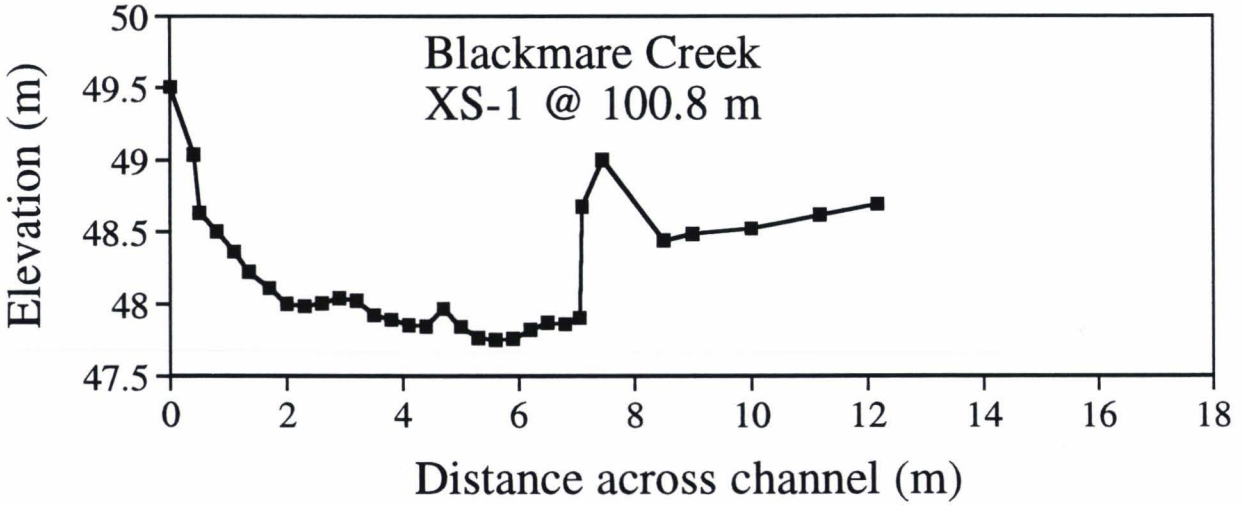

Elev channel bed = -0.01000 X + 49.851
Elev water surf = -0.01000 X + 50.039
Elev bankfull = -0.01000 X + 50.449
center bed
RB WSE
LBF
RBF
LB WSe
bankfulls
LHW
RHW
Column 20
Elevation (m)
Distance (m)
51
50
49
48
47
0
20
40
60
80
100
120
140
160
180
200
220
240
260

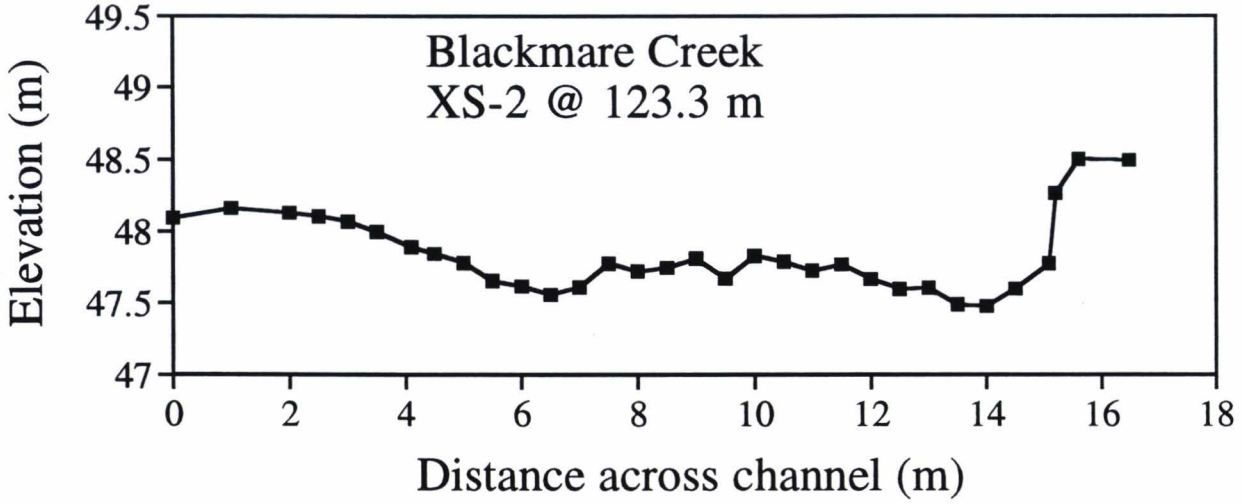

Thompson Creek
Elev channel bed = -0.01529 X + 49.967
Elev water surf = -0.01529 X + 50.151
Elev bankfull = -0.01529 X + 50.370
LB WSE
RB WSE
RBF
HW elev
BED
LBF
Bankfulls
Elevation (m)
Distance (m)
50.5
50
49.5
49
48.5
48
47.5
0
25
50
75
100
125
150

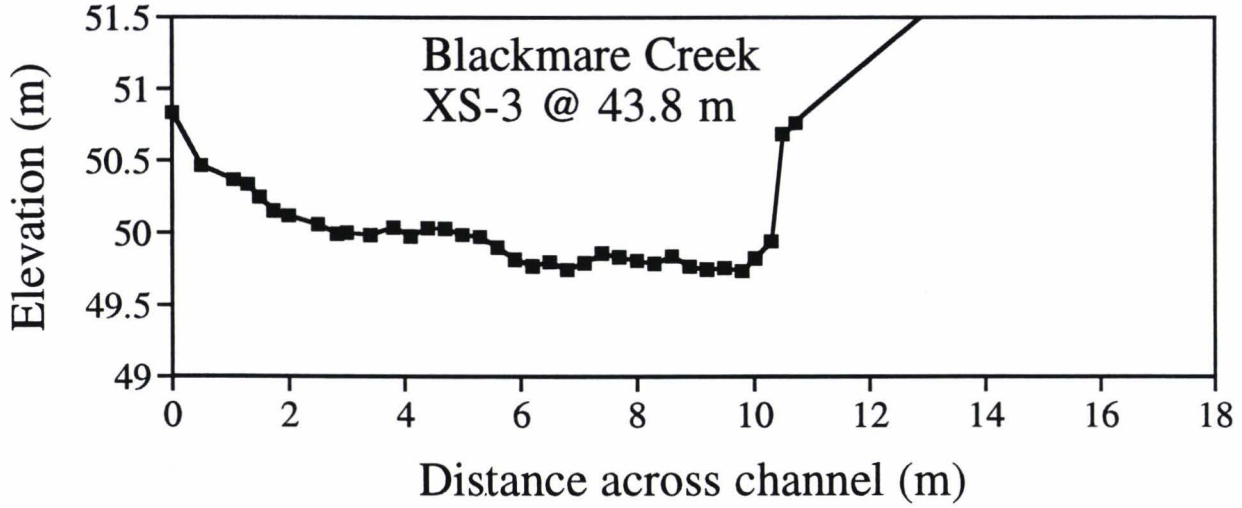

Valley Creek
Elev channel bed = -0.00422 X + 49.864
Elev water surf = -0.00422 X + 50.211
Elev bankfull = -0.00422 X + 50.765
LB WSE
center bed
RB WSE
LBF Elev
RBF Elev
LHW
Elevation (m)
Distance (m)
52
51
50
49
48
47
0
100
200
300
400
500

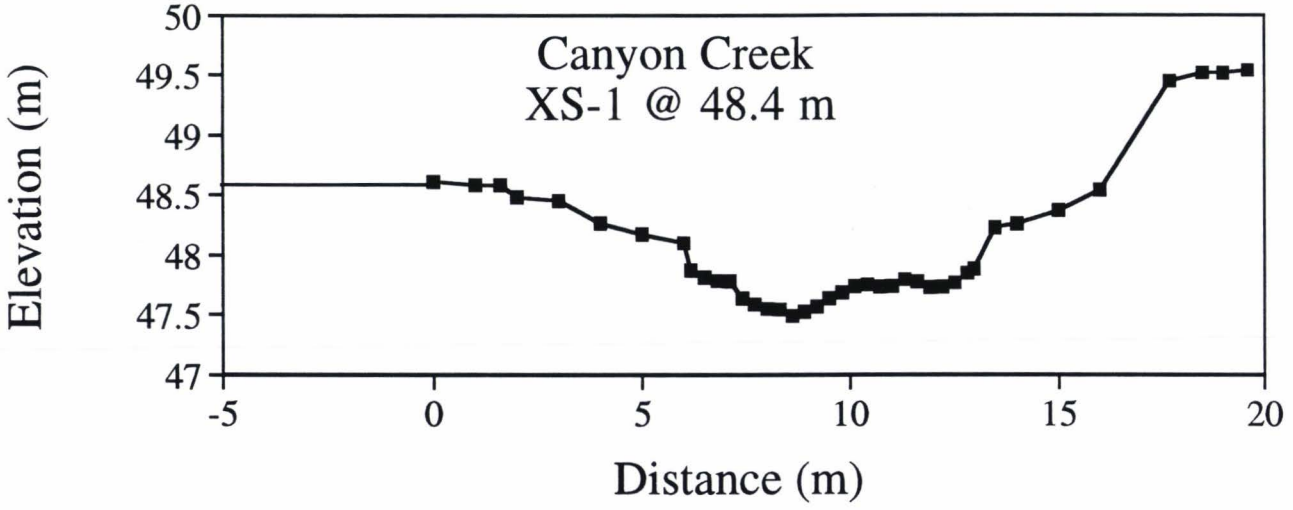
Buckhorn Creek

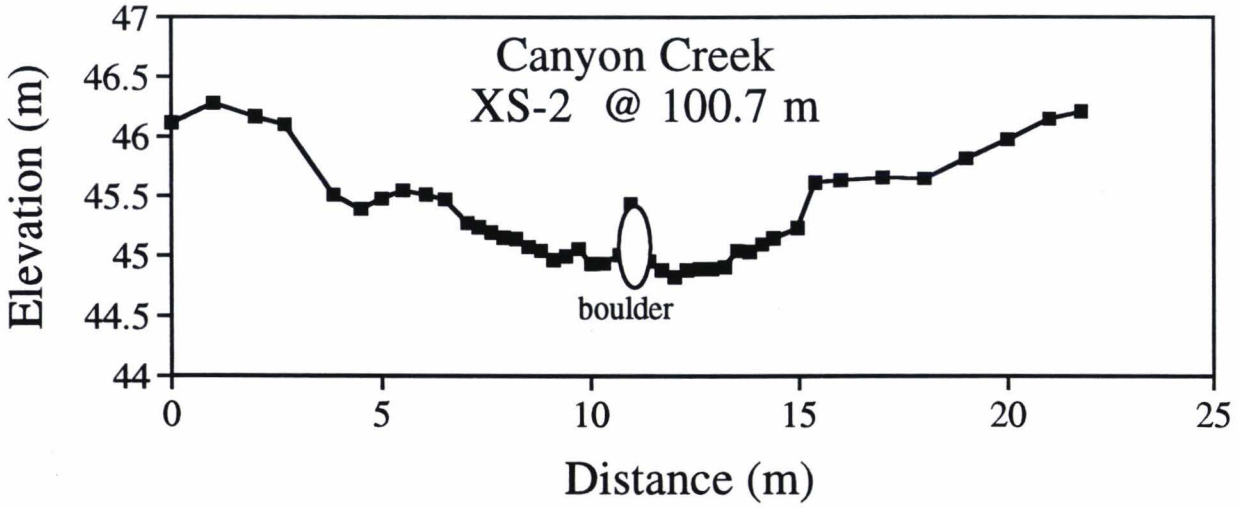


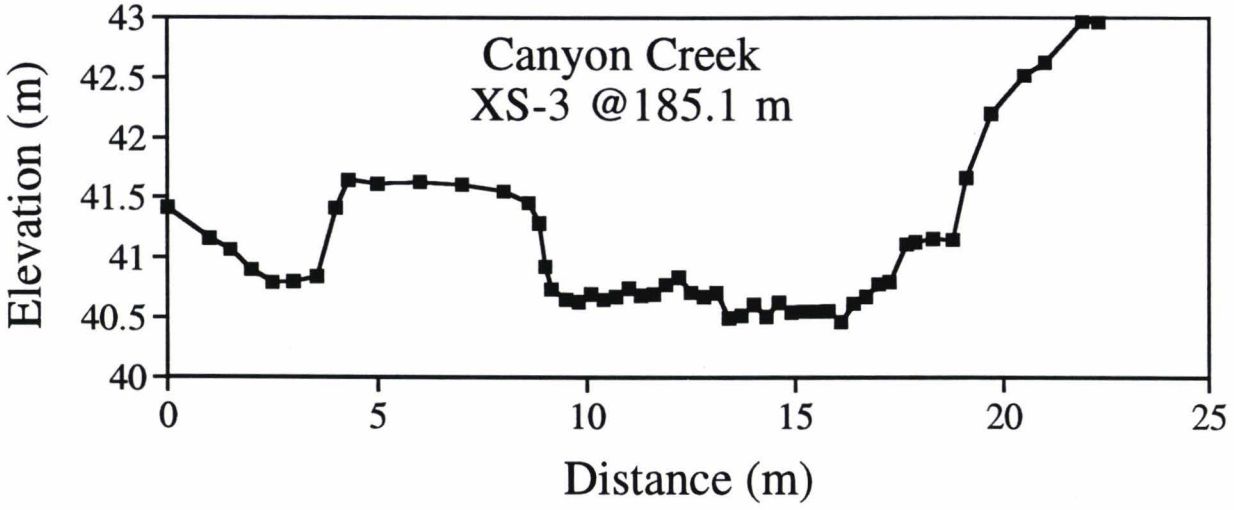

Blackmare Creek
XS-1 @ 100.8 m
Elevation (m)
50
49.5
49
48.5
48
47.5
0
2
4
6
8
10
12
14
16
18
Distance across channel (m)

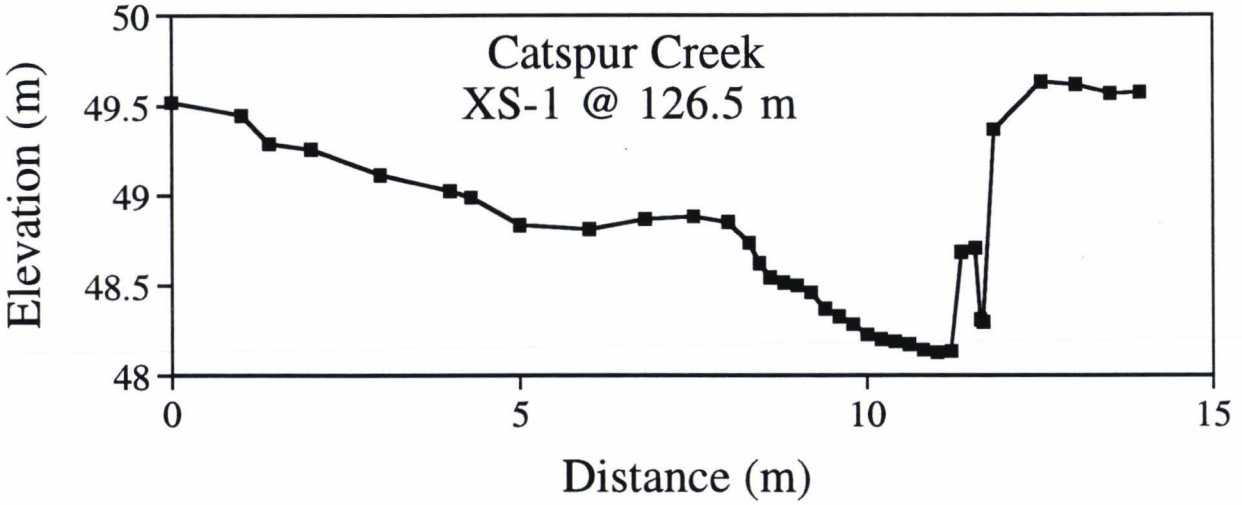

Blackmare Creek
XS-2 @ 123.3 m
Elevation (m)
49.5
49
48.5
48
47.5
47
0
2
4
6
8
10
12
14
16
18
Distance across channel (m)

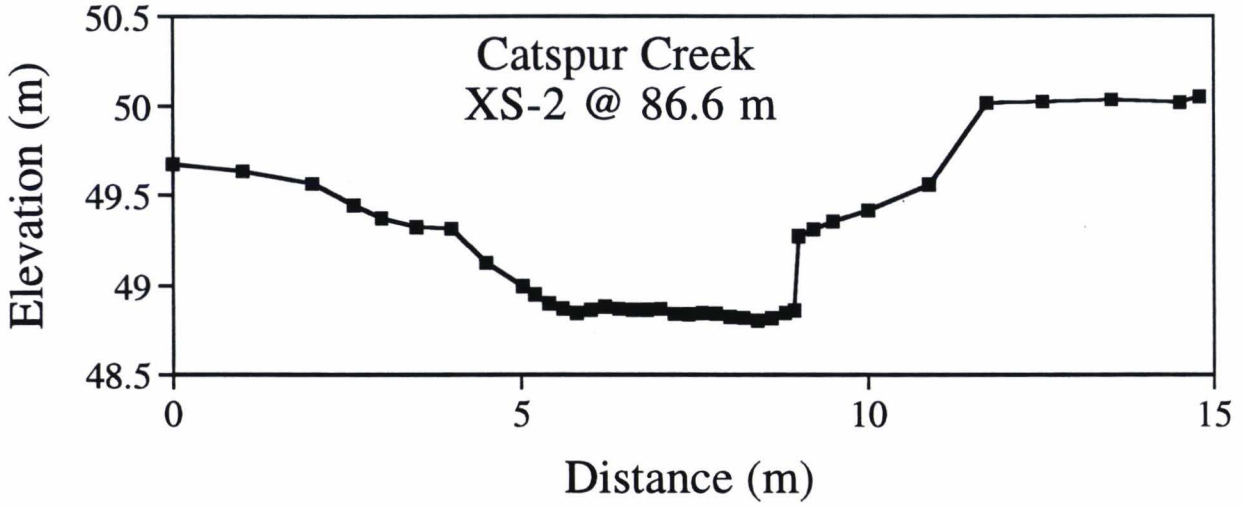

Blackmare Creek
XS-3 @ 43.8 m
Elevation (m)
51.5
51
50.5
50
49.5
49
0
2
4
6
8
10
12
14
16
18
Distance across channel (m)

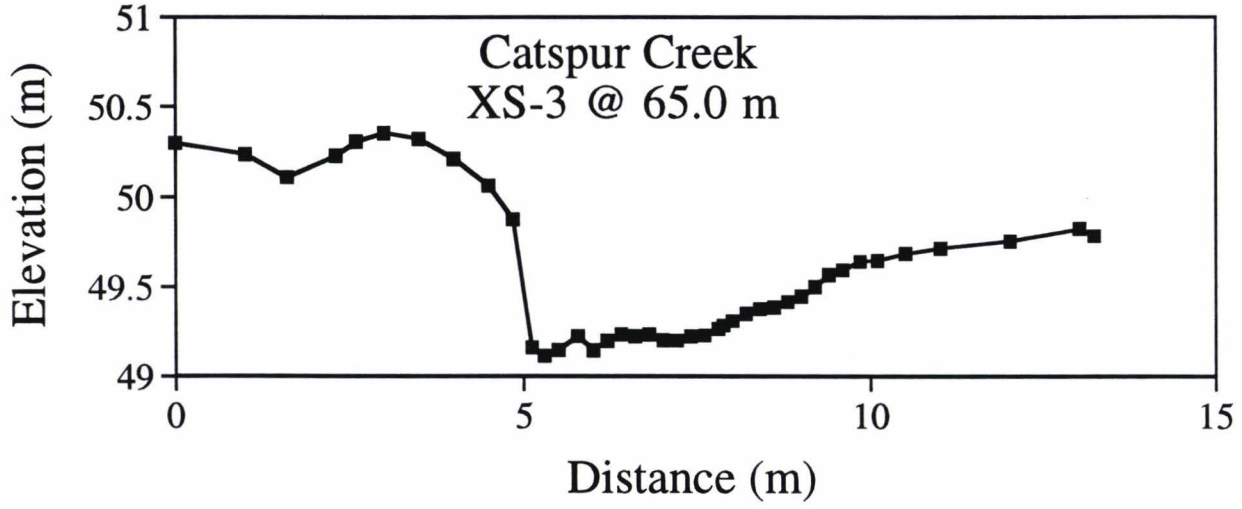

Canyon Creek
XS-1 @ 48.4 m
Elevation (m)
50
49.5
49
48.5
48
47.5
47
-5
0
5
10
15
20
Distance (m)

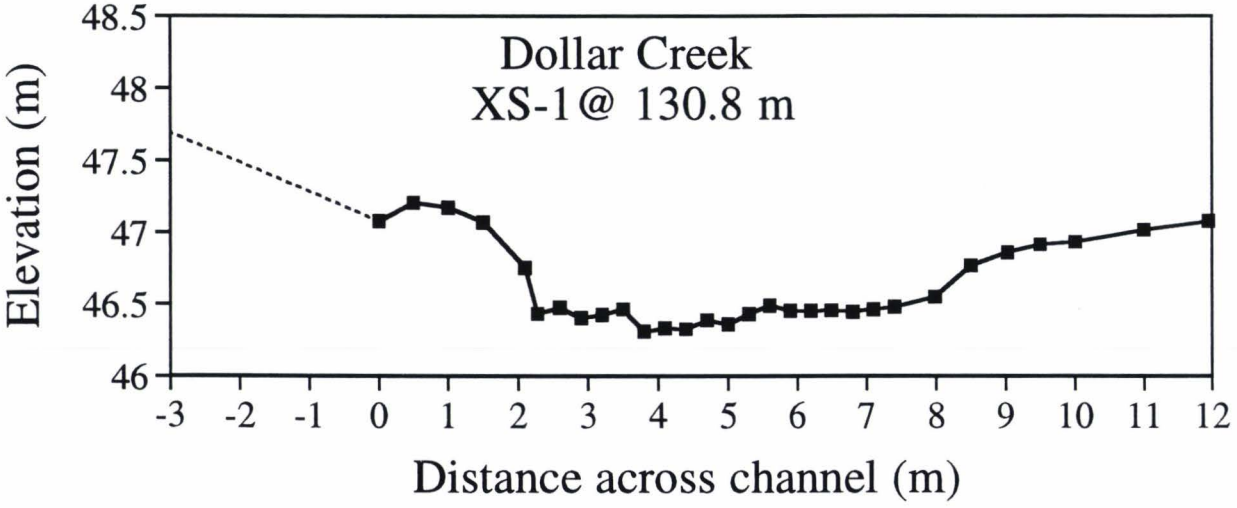

Canyon Creek
XS-2 @ 100.7 m
boulder
Elevation (m)
47
46.5
46
45.5
45
44.5
44
0
5
10
15
20
25
Distance (m)

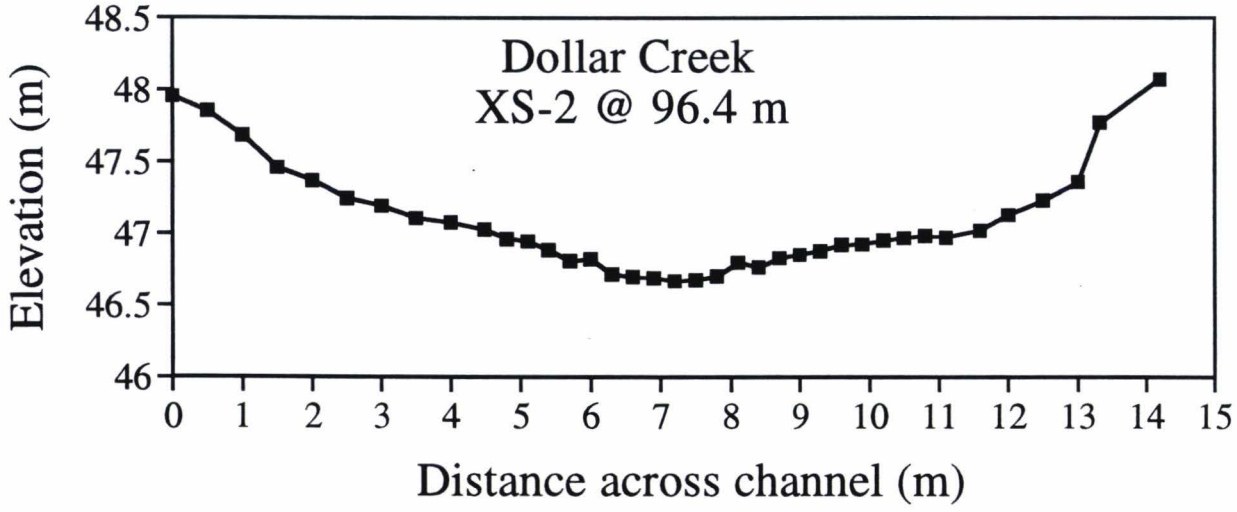

Canyon Creek
XS-3 @185.1 m
Elevation (m)
43
42.5
42
41.5
41
40.5
40
0
5
10
15
20
25
Distance (m)

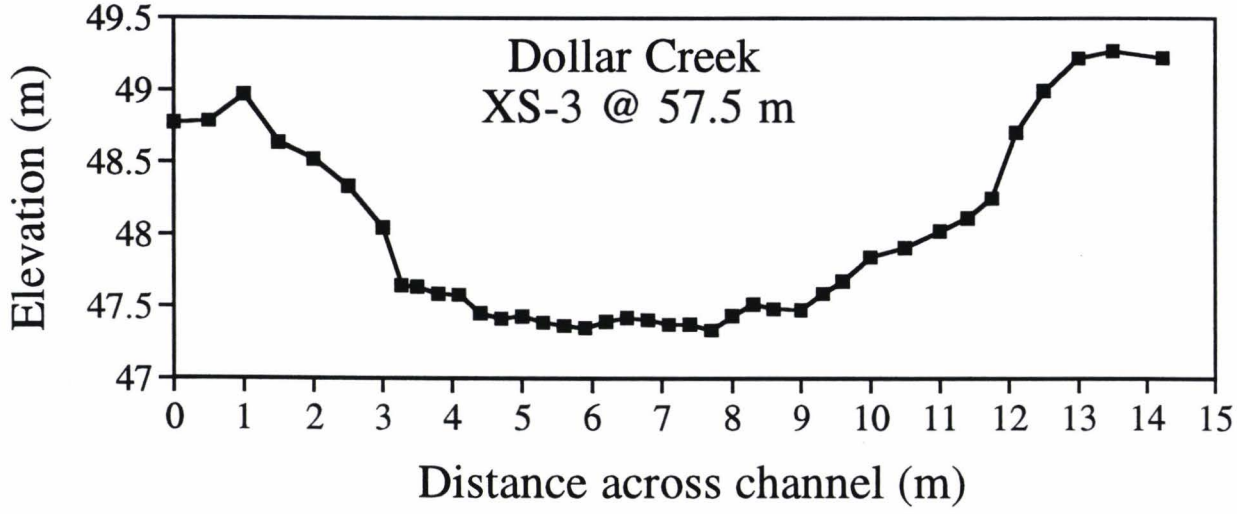

Catspur Creek
XS-1 @ 126.5 m
Elevation (m)
50
49.5
49
48.5
48
0
5
10
15
Distance (m)

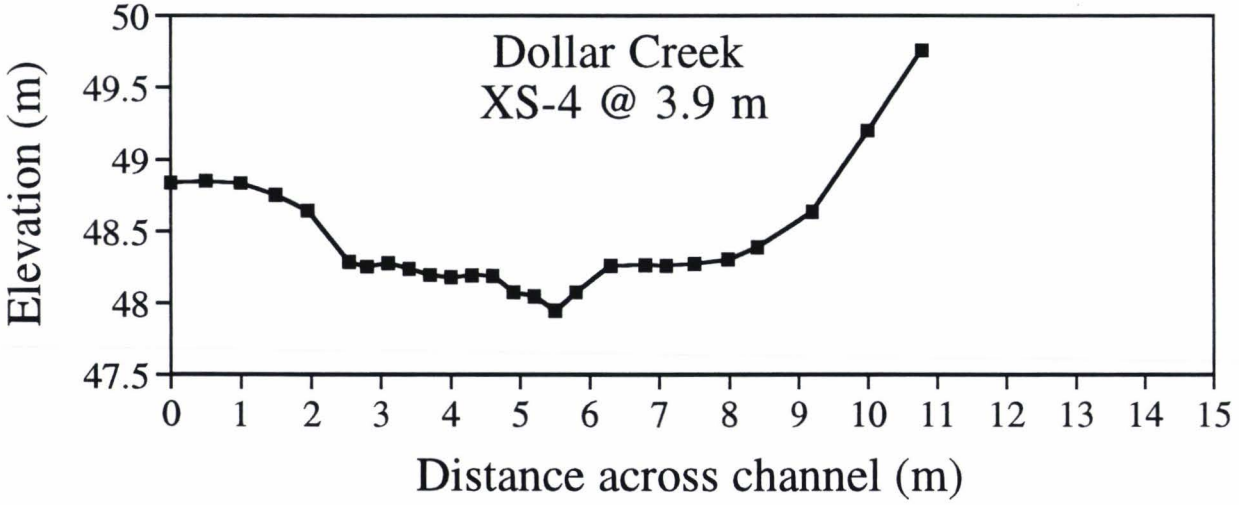

Catspur Creek
XS-2 @ 86.6 m
Elevation (m)
50.5
50
49.5
49
48.5
0
5
10
15
Distance (m)

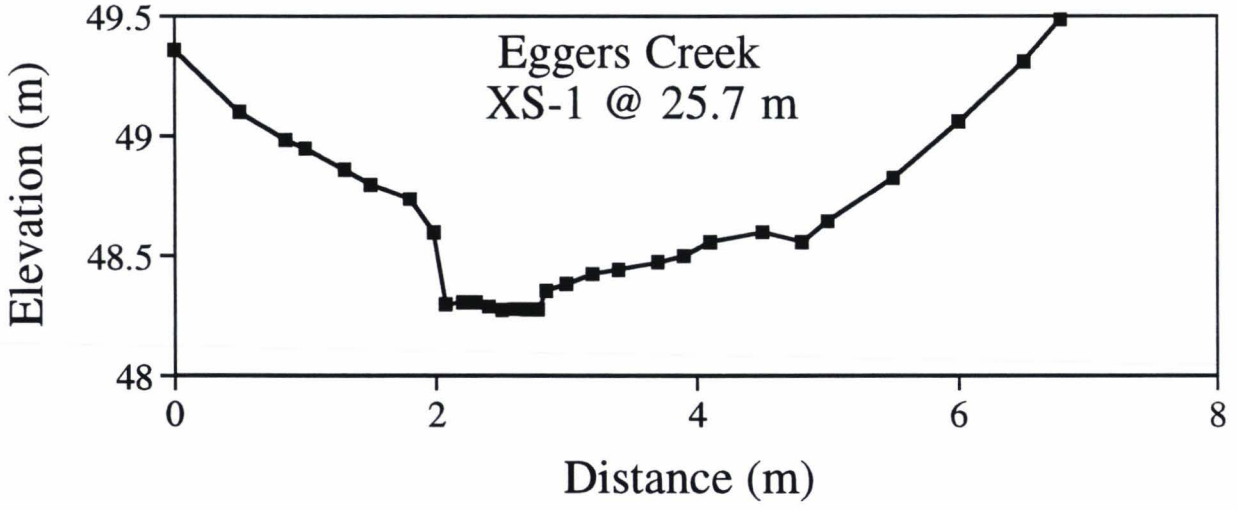

Catspur Creek
XS-3 @ 65.0 m
Elevation (m)
51
50.5
50
49.5
49
0
5
10
15
Distance (m)

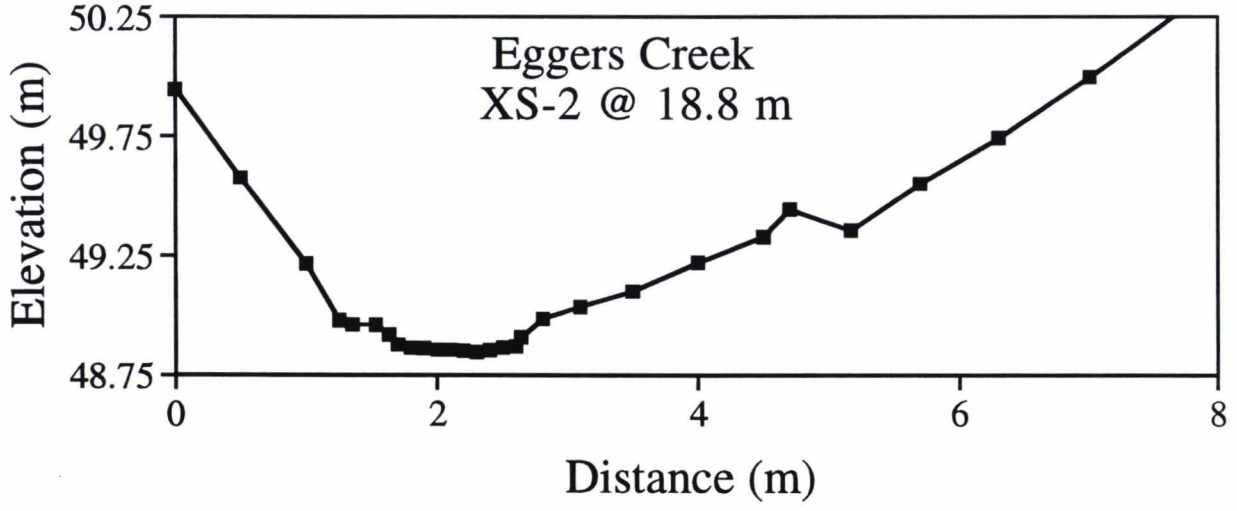

Dollar Creek
XS-1@ 130.8 m
Elevation (m)
48.5
48
47.5
47
46.5
46
-3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12
Distance across channel (m)

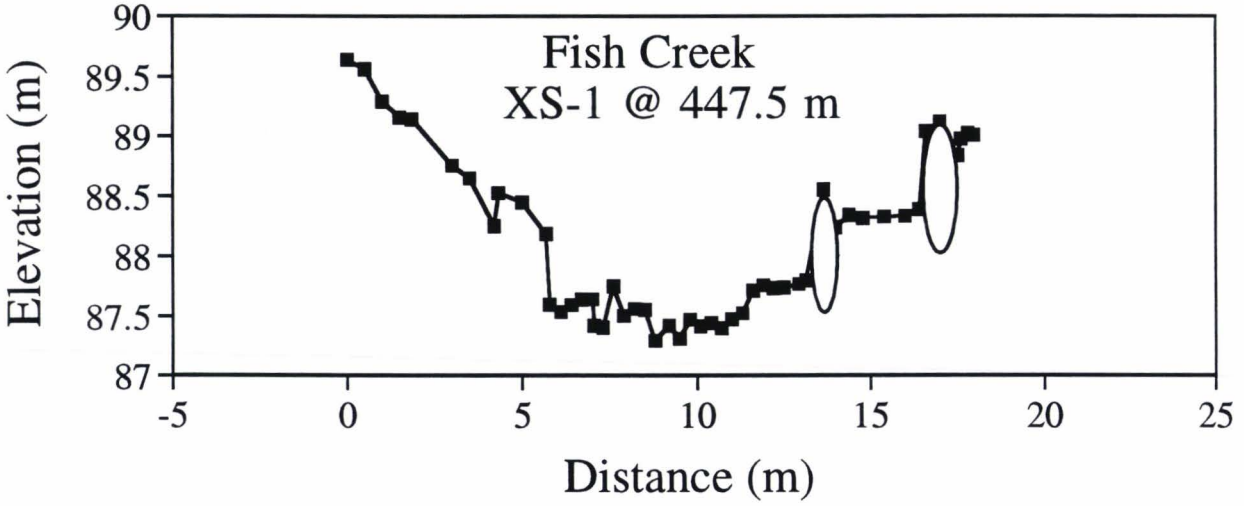

Dollar Creek
XS-2 @ 96.4 m
Elevation (m)
48.5
48
47.5
47
46.5
46
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Distance across channel (m)

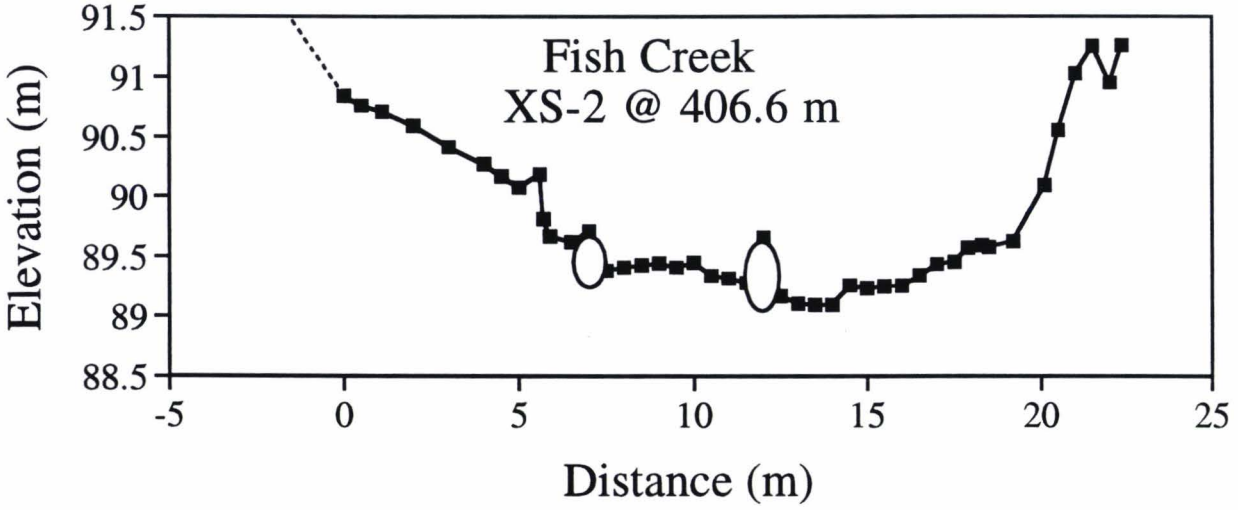

Dollar Creek
XS-3 @ 57.5 m
Elevation (m)
49.5
49
48.5
48
47.5
47
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Distance across channel (m)

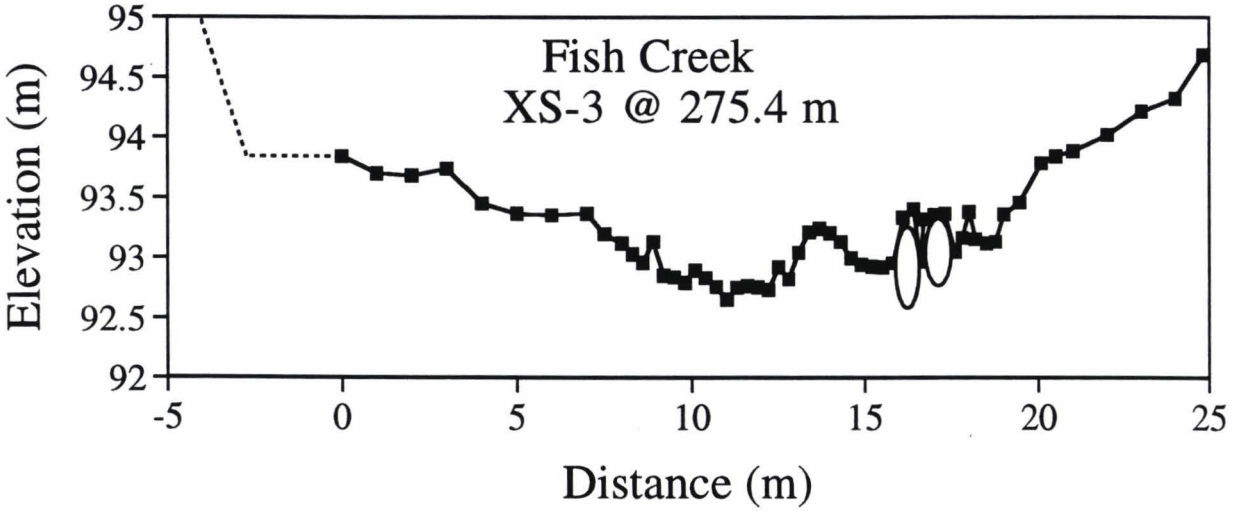

Dollar Creek
XS-4 @ 3.9 m
Elevation (m)
50
49.5
49
48.5
48
47.5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Distance across channel (m)

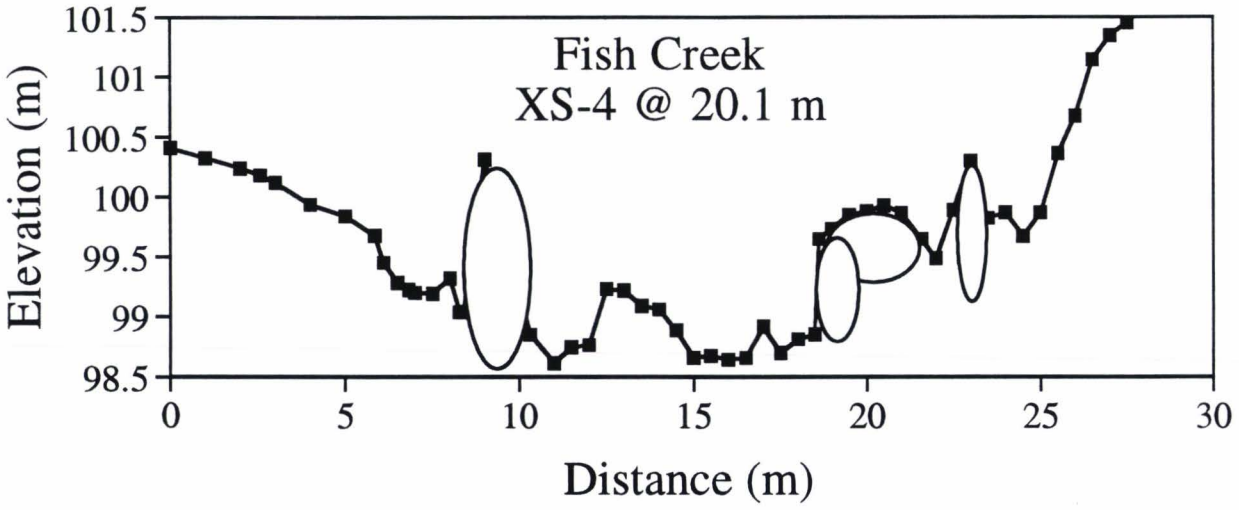

Eggers Creek
XS-1 @ 25.7 m
Elevation (m)
49.5
49
48.5
48
0
2
4
6
8
Distance (m)

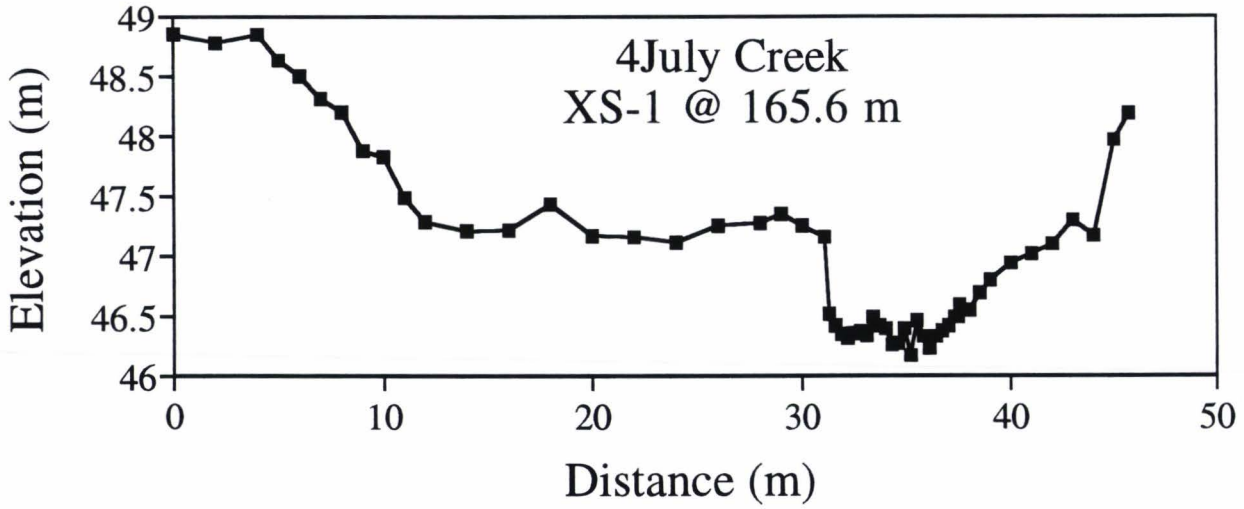

Eggers Creek
XS-2 @ 18.8 m
Elevation (m)
50.25
49.75
49.25
48.75
0
2
4
6
8
Distance (m)

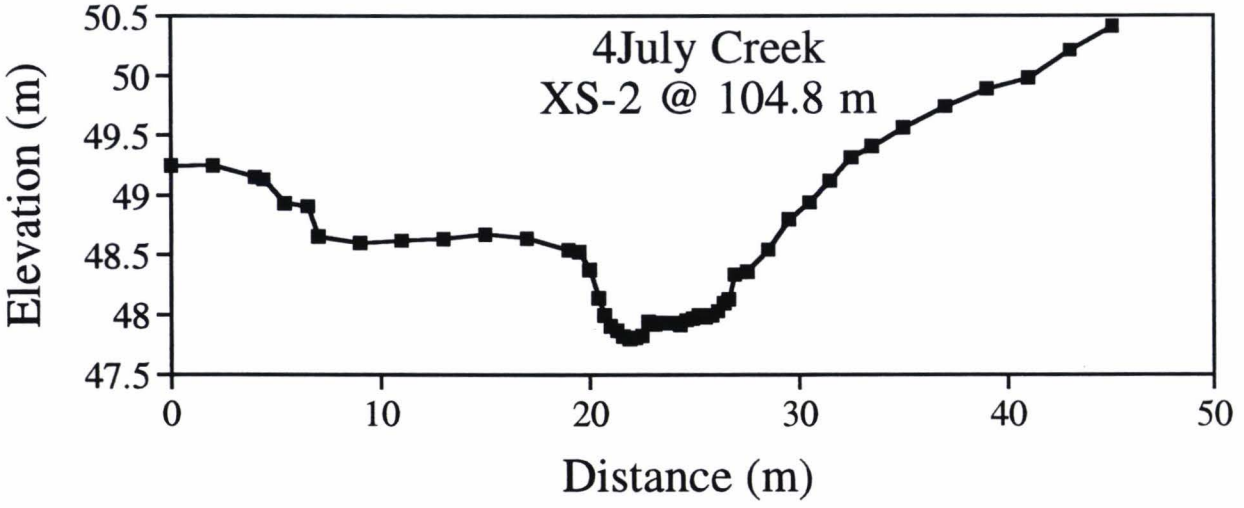

Fish Creek
XS-1 @ 447.5 m
Elevation (m)
90
89.5
89
88.5
88
87.5
87
-5
0
5
10
15
20
25
Distance (m)

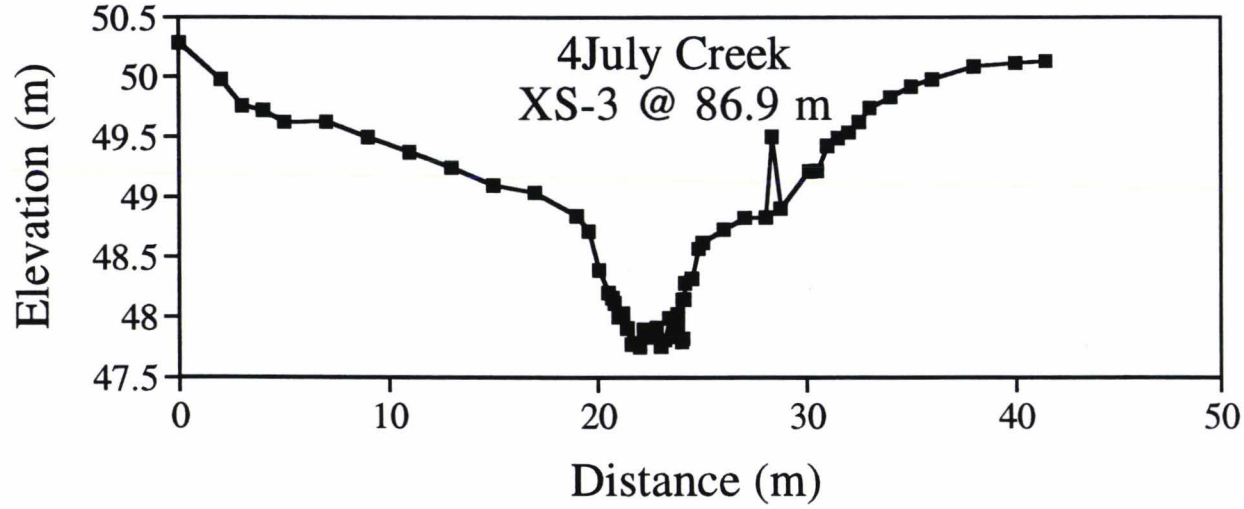

Fish Creek
XS-2 @ 406.6 m
Elevation (m)
91.5
91
90.5
90
89.5
89
88.5
-5
0
5
10
15
20
25
Distance (m)

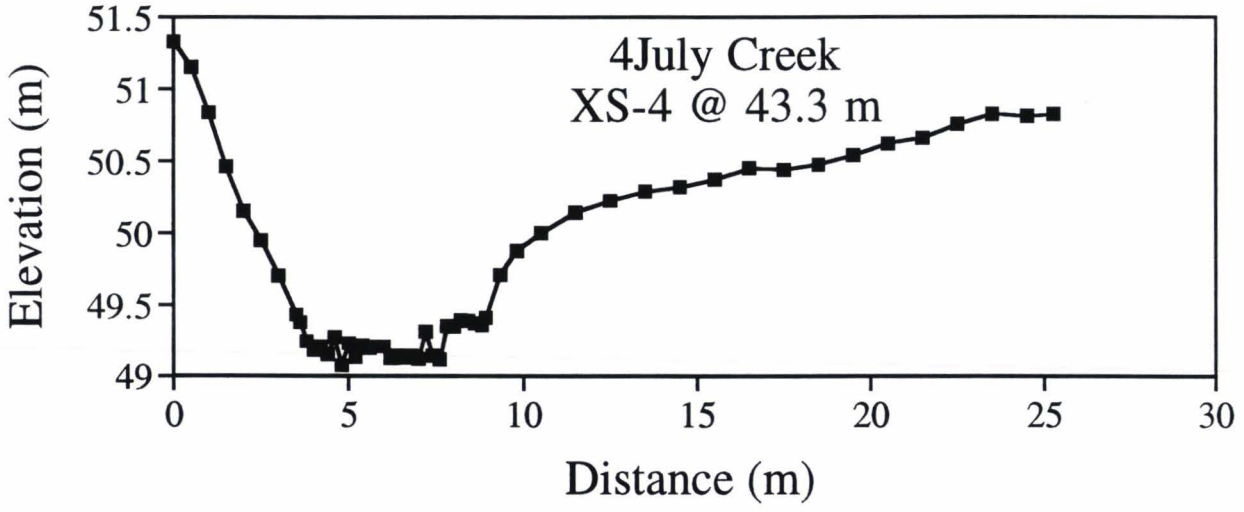

Fish Creek
XS-3 @ 275.4 m
Elevation (m)
95
94.5
94
93.5
93
92.5
92
-5
0
5
10
15
20
25
Distance (m)

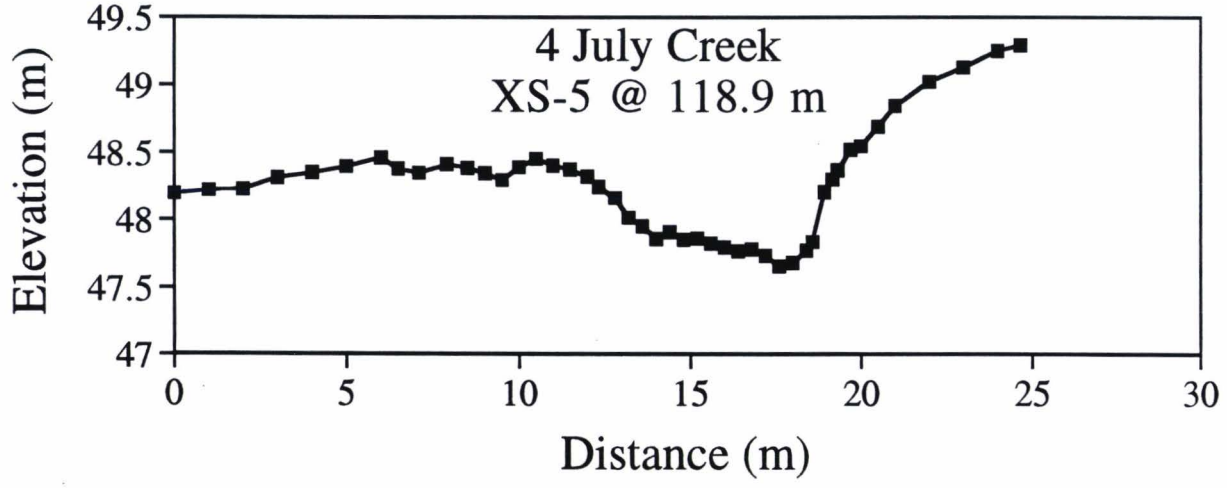

Fish Creek
XS-4 @ 20.1 m
Elevation (m)
101.5
101
100.5
100
99.5
99
98.5
0
5
10
15
20
25
30
Distance (m)

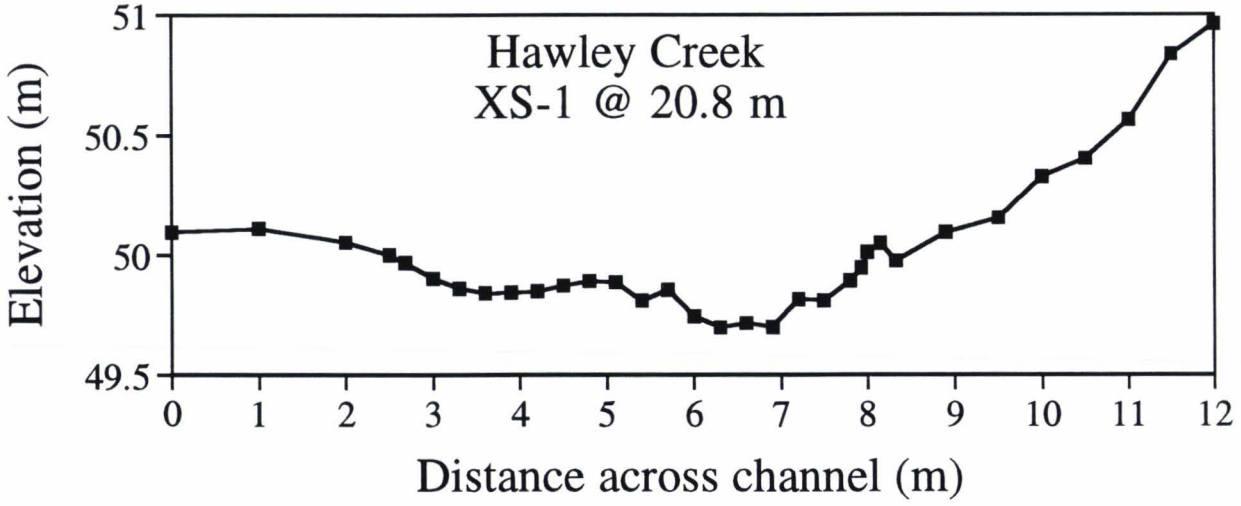

4July Creek
XS-1 @ 165.6 m
Elevation (m)
49
48.5
48
47.5
47
46.5
46
0
10
20
30
40
50
Distance (m)

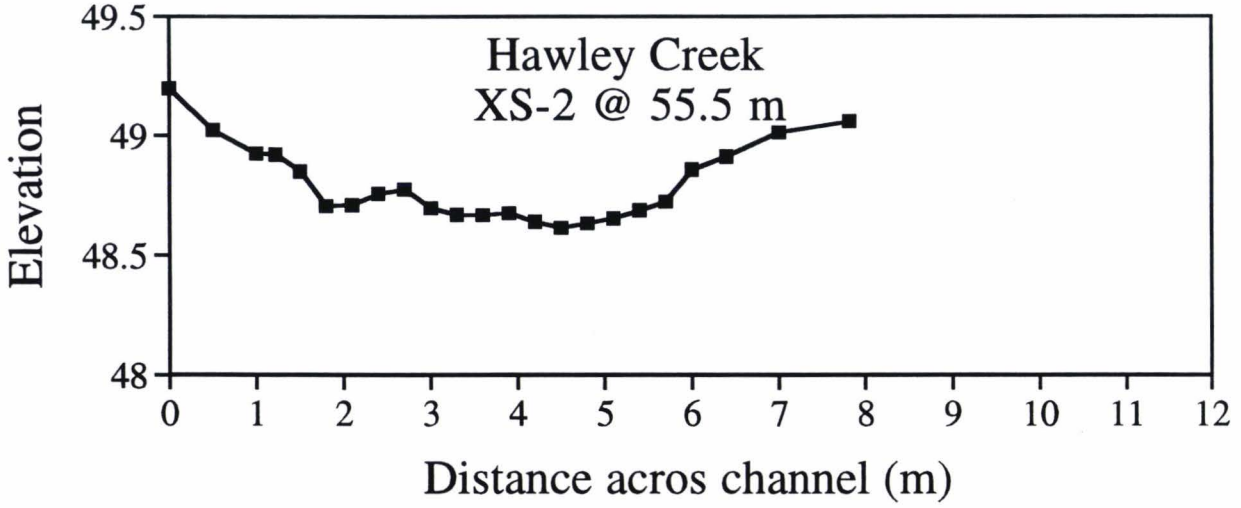

4July Creek
XS-2 @ 104.8 m
Elevation (m)
50.5
50
49.5
49
48.5
48
47.5
0
10
20
30
40
50
Distance (m)

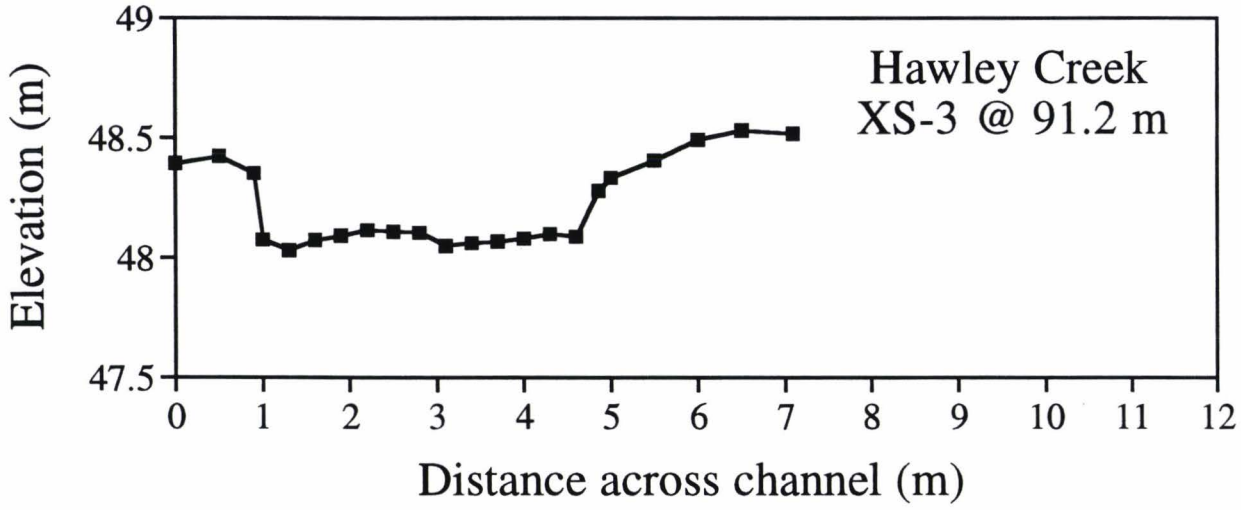

4July Creek
XS-3 @ 86.9 m
Elevation (m)
50.5
50
49.5
49
48.5
48
47.5
0
10
20
30
40
50
Distance (m)

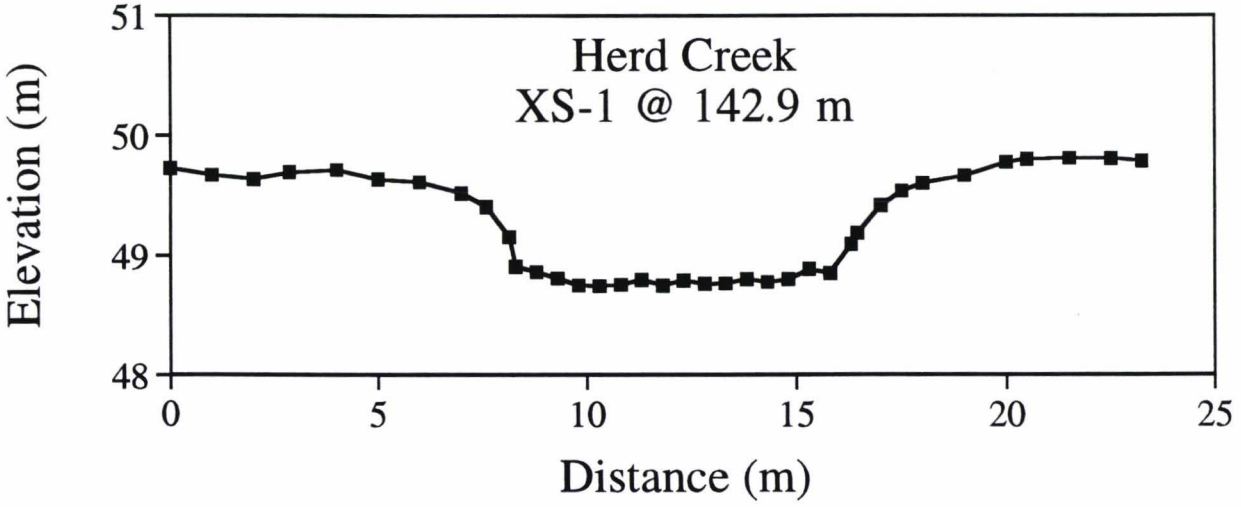

4July Creek
XS-4 @ 43.3 m
Elevation (m)
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
30
Distance (m)

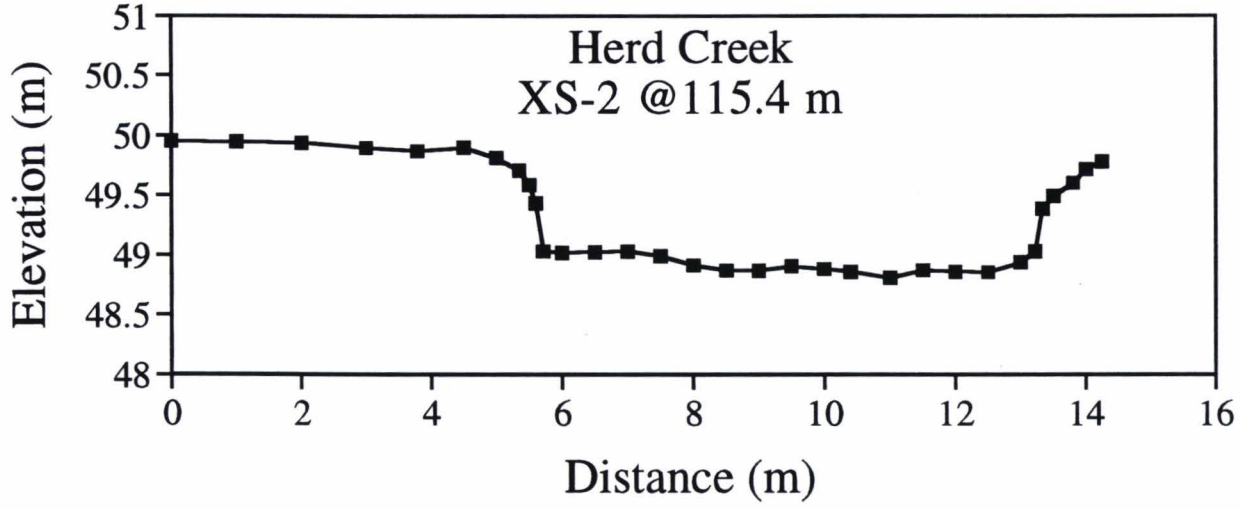

4 July Creek
XS-5 @ 118.9 m
Elevation (m)
49.5
49
48.5
48
47.5
47
0
5
10
15
20
25
30
Distance (m)

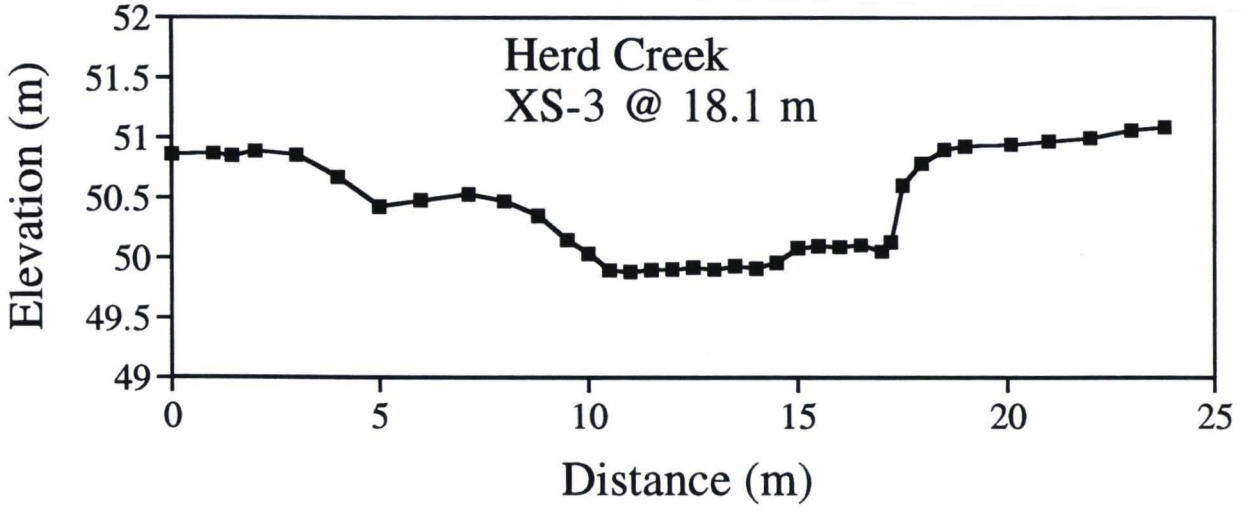

Hawley Creek
XS-1 @ 20.8 m
Elevation (m)
51
50.5
50
49.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance across channel (m)

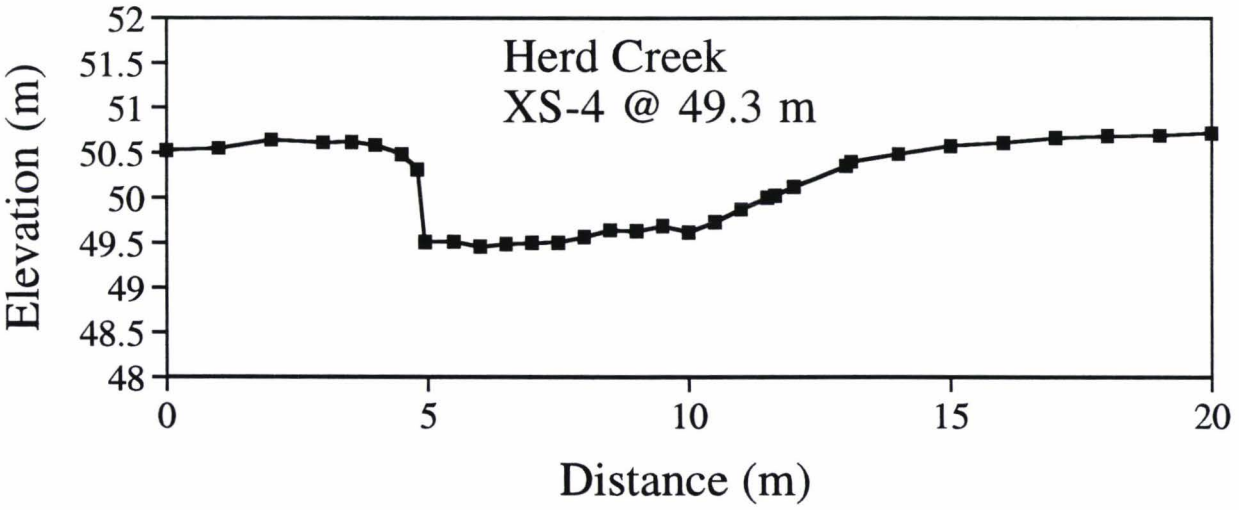

Hawley Creek
XS-2 @ 55.5 m
Elevation
49.5
49
48.5
48
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance acros channel (m)

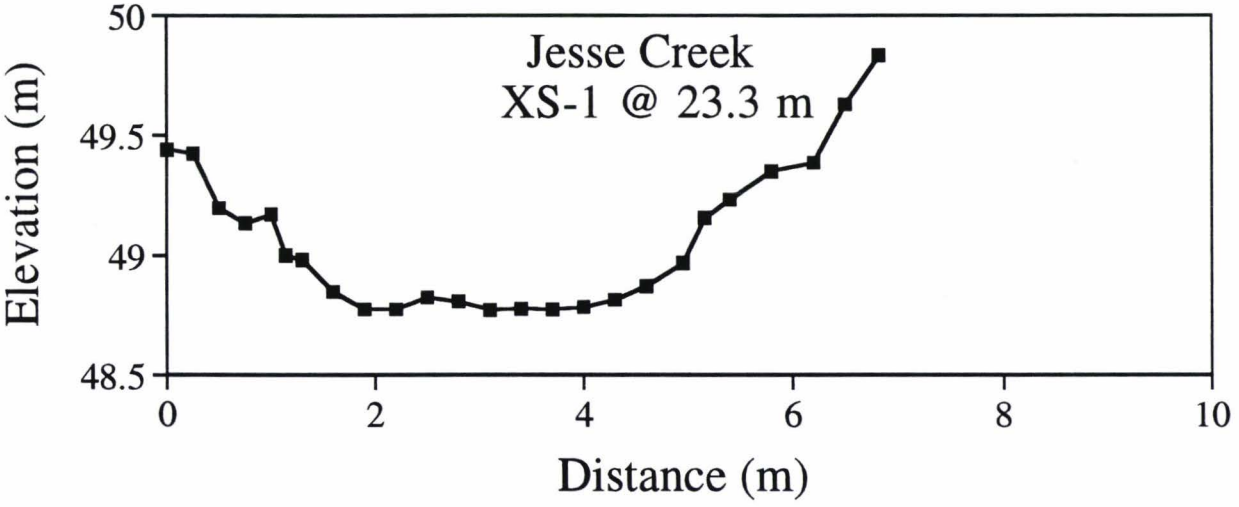

Hawley Creek
XS-3 @ 91.2 m
Elevation (m)
49
48.5
48
47.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance across channel (m)

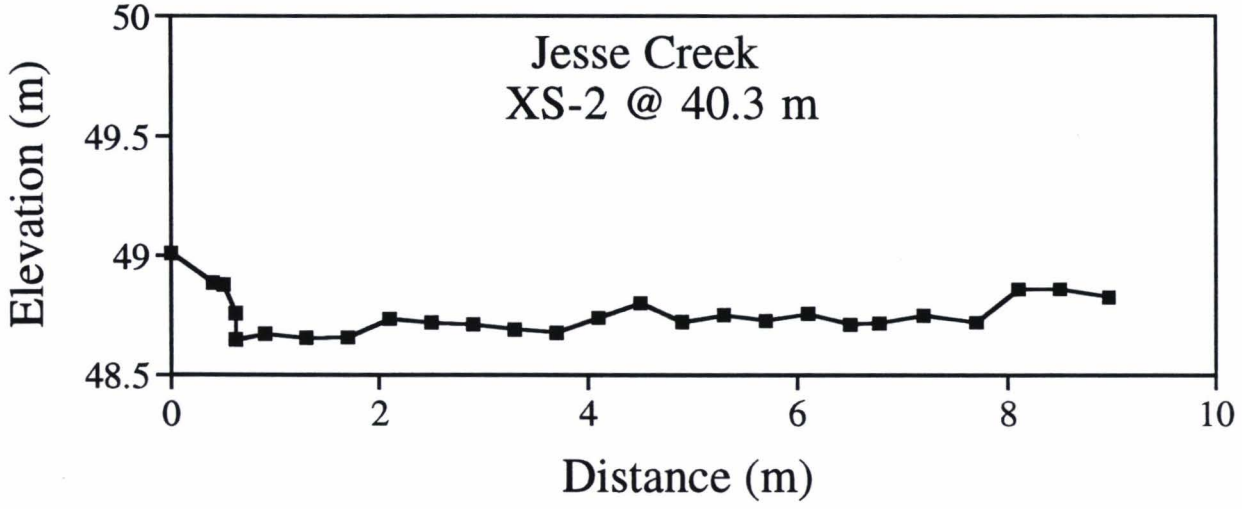

Herd Creek
XS-1 @ 142.9 m
Elevation (m)
51
50
49
48
0
5
10
15
20
25
Distance (m)

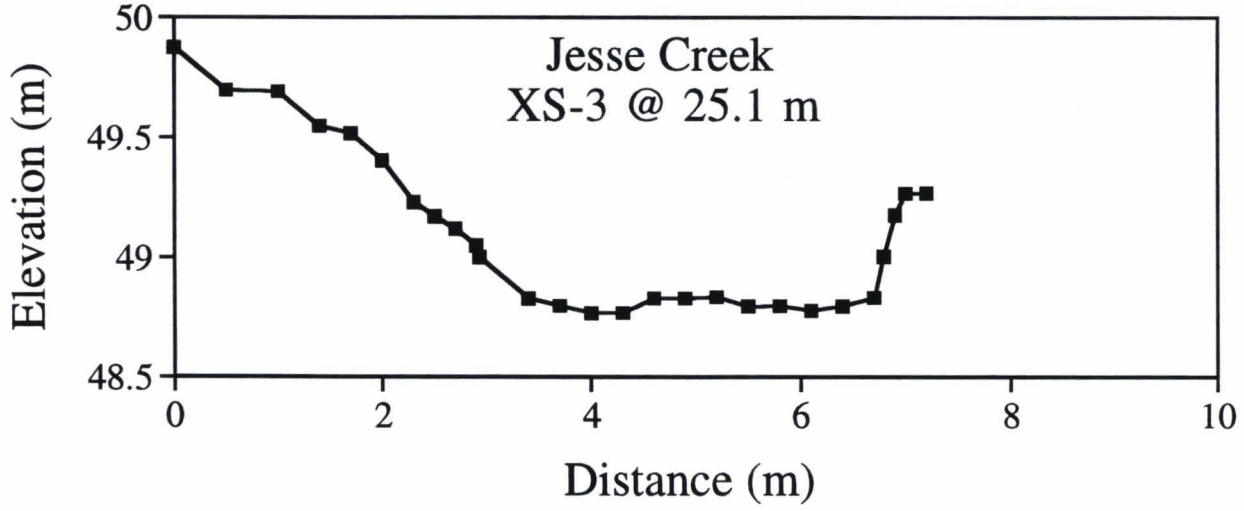

Herd Creek
XS-2 @115.4 m
Elevation (m)
51
50.5
50
49.5
49
48.5
48
0
2
4
6
8
10
12
14
16
Distance (m)

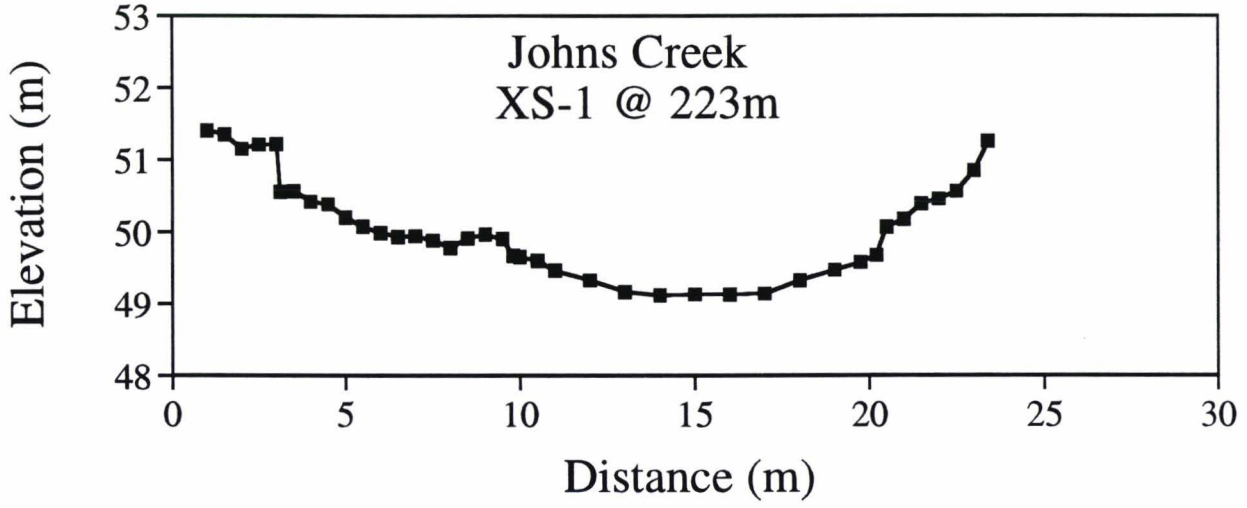

Herd Creek
XS-3 @ 18.1 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
Distance (m)

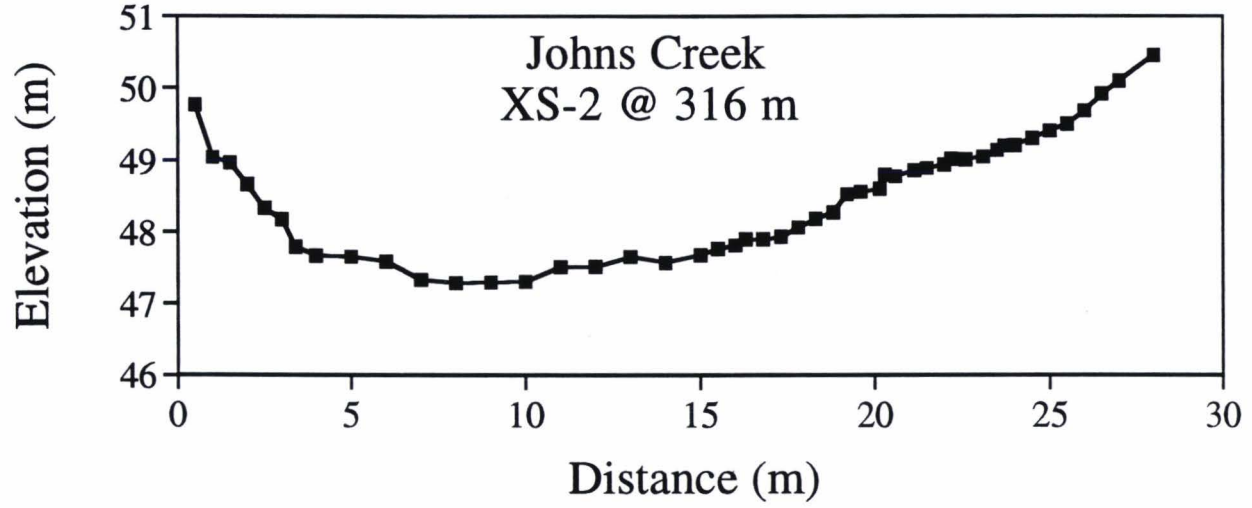

Herd Creek
XS-4 @ 49.3 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
48.5
48
0
5
10
15
20
Distance (m)

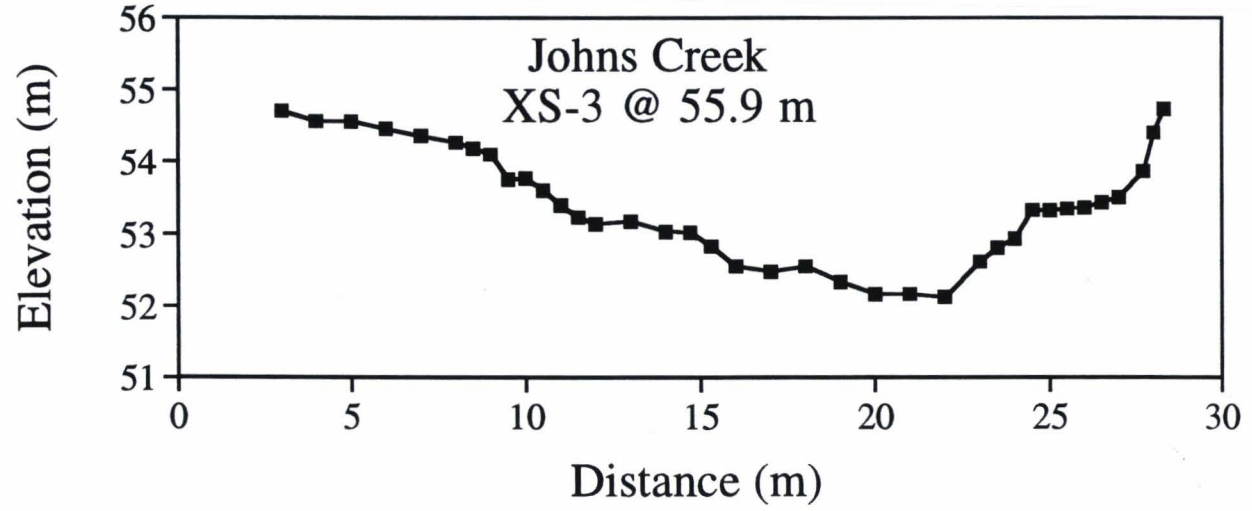

Jesse Creek
XS-1 @ 23.3 m
Elevation (m)
50
49.5
49
48.5
0
2
4
6
8
10
Distance (m)

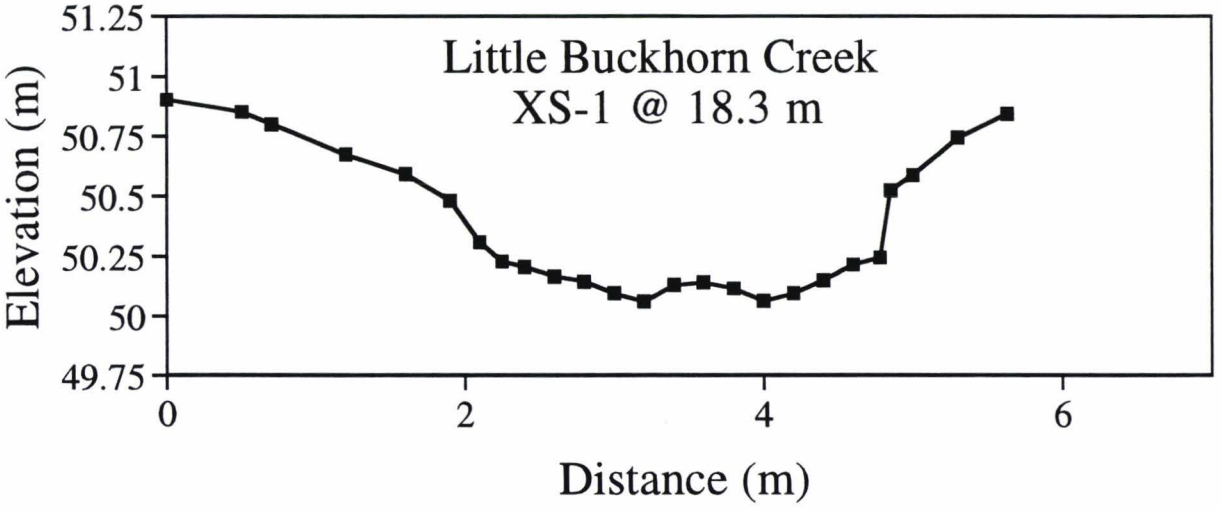

Jesse Creek
XS-2 @ 40.3 m
Elevation (m)
50
49.5
49
48.5
0
2
4
6
8
10
Distance (m)

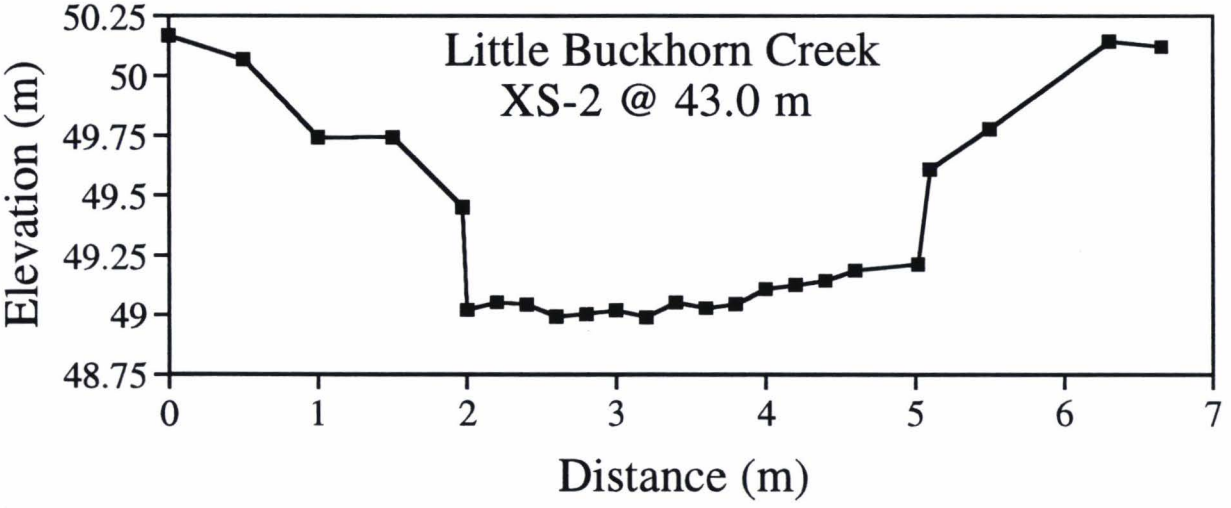

Jesse Creek
XS-3 @ 25.1 m
Elevation (m)
50
49.5
49
48.5
0
2
4
6
8
10
Distance (m)

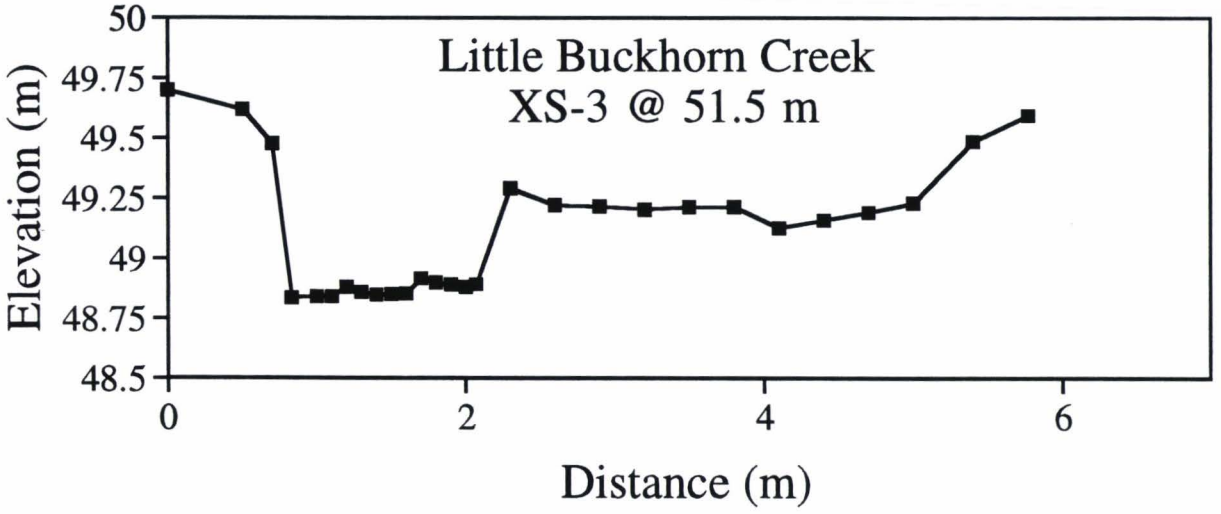

Johns Creek
XS-1 @ 223m
Elevation (m)
Distance (m)
53
52
51
50
49
48
0
5
10
15
20
25
30

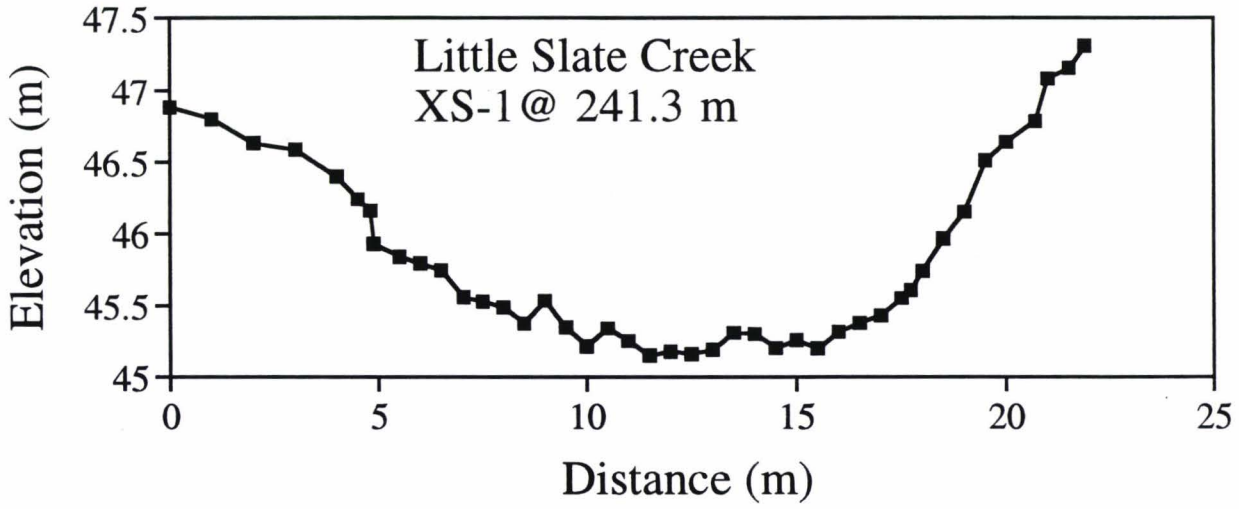

Johns Creek
XS-2 @ 316 m
Elevation (m)
Distance (m)
51
50
49
48
47
46
0
5
10
15
20
25
30

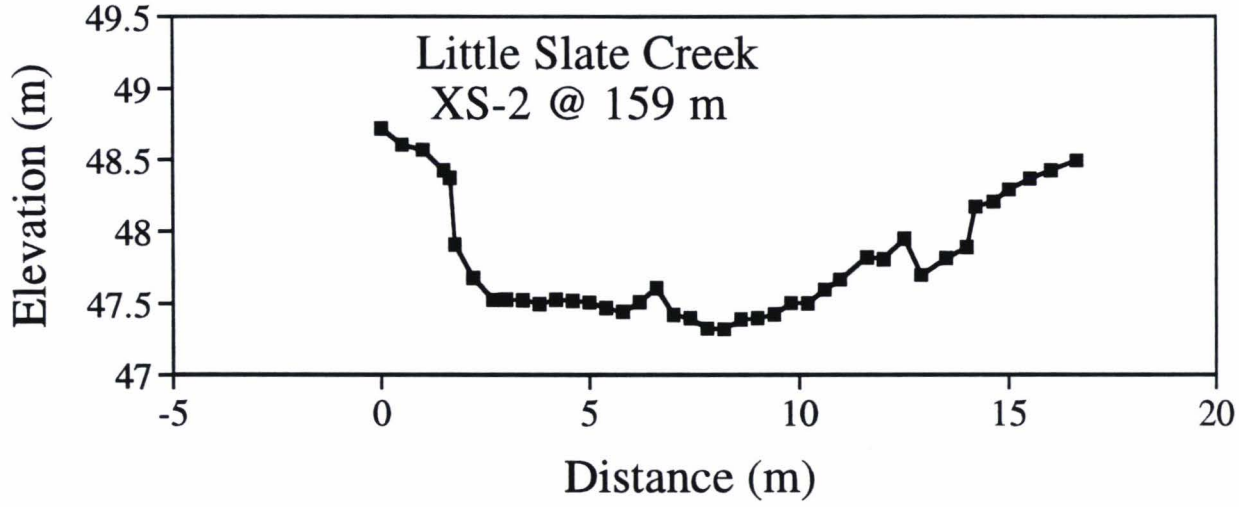

Johns Creek
XS-3 @ 55.9 m
Elevation (m)
Distance (m)
56
55
54
53
52
51
0
5
10
15
20
25
30

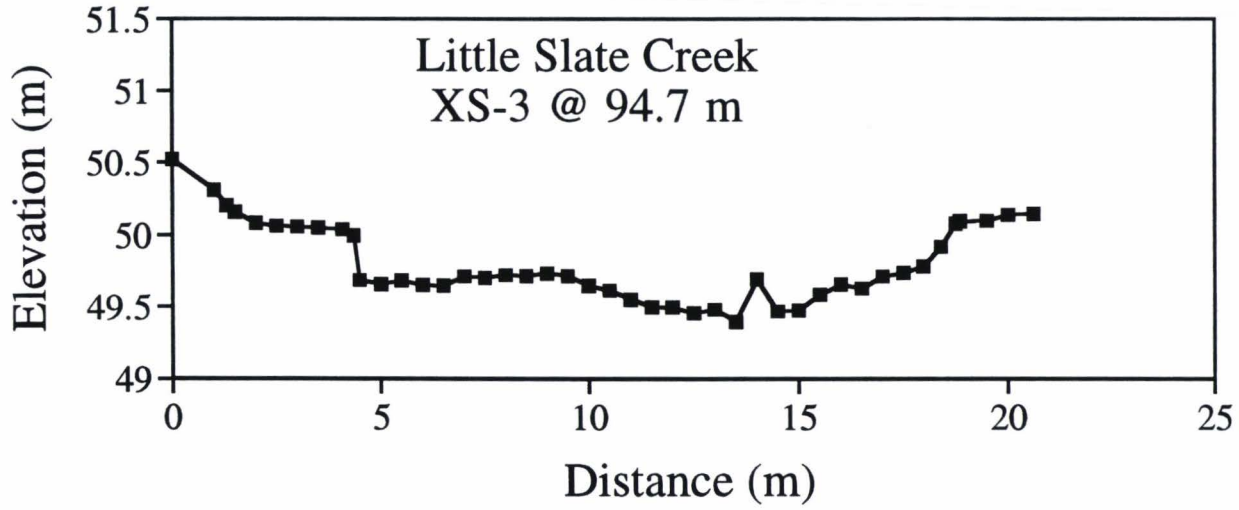

Little Buckhorn Creek
XS-1 @ 18.3 m
Elevation (m)
51.25
51
50.75
50.5
50.25
50
49.75
0
2
4
6
Distance (m)

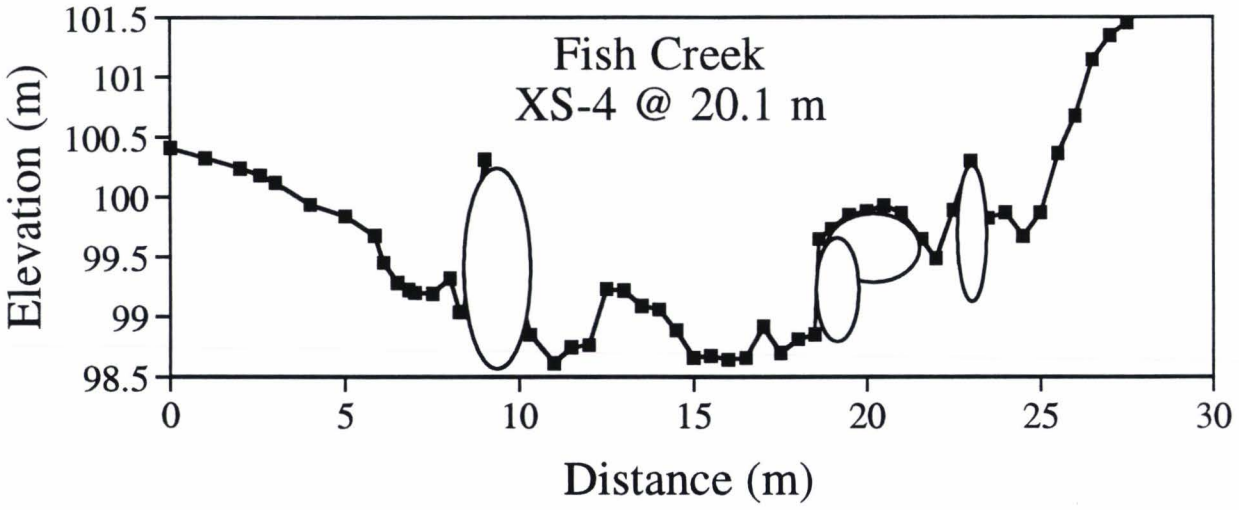

Little Buckhorn Creek
XS-2 @ 43.0 m
Elevation (m)
50.25
50
49.75
49.5
49.25
49
48.75
0
1
2
3
4
5
6
7
Distance (m)

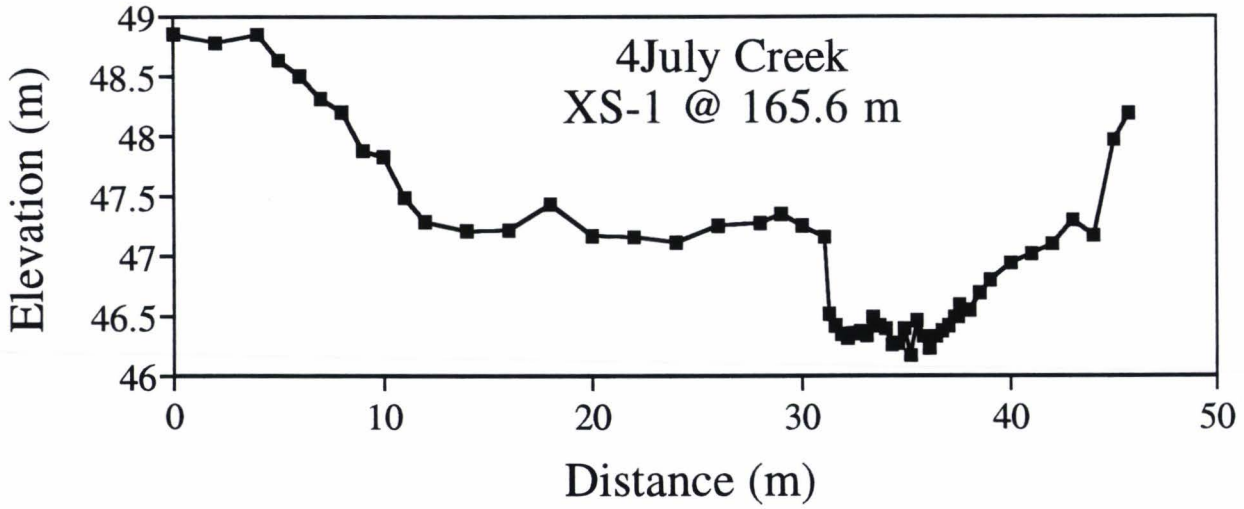

Little Buckhorn Creek
XS-3 @ 51.5 m
Elevation (m)
50
49.75
49.5
49.25
49
48.75
48.5
0
2
4
6
Distance (m)

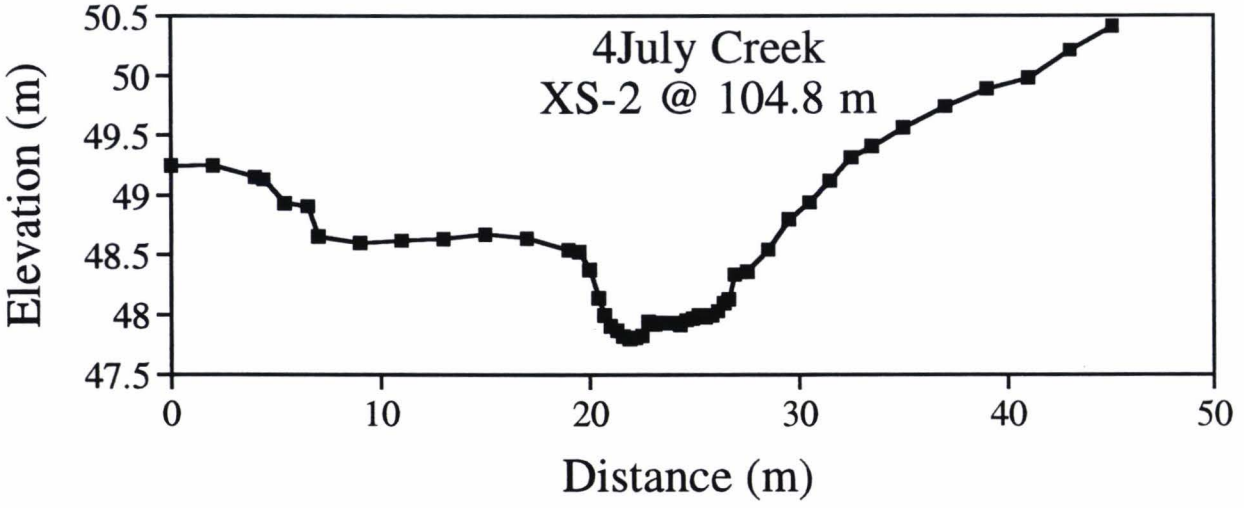

Little Slate Creek
XS-1@ 241.3 m
Elevation (m)
47.5
47
46.5
46
45.5
45
0
5
10
15
20
25
Distance (m)

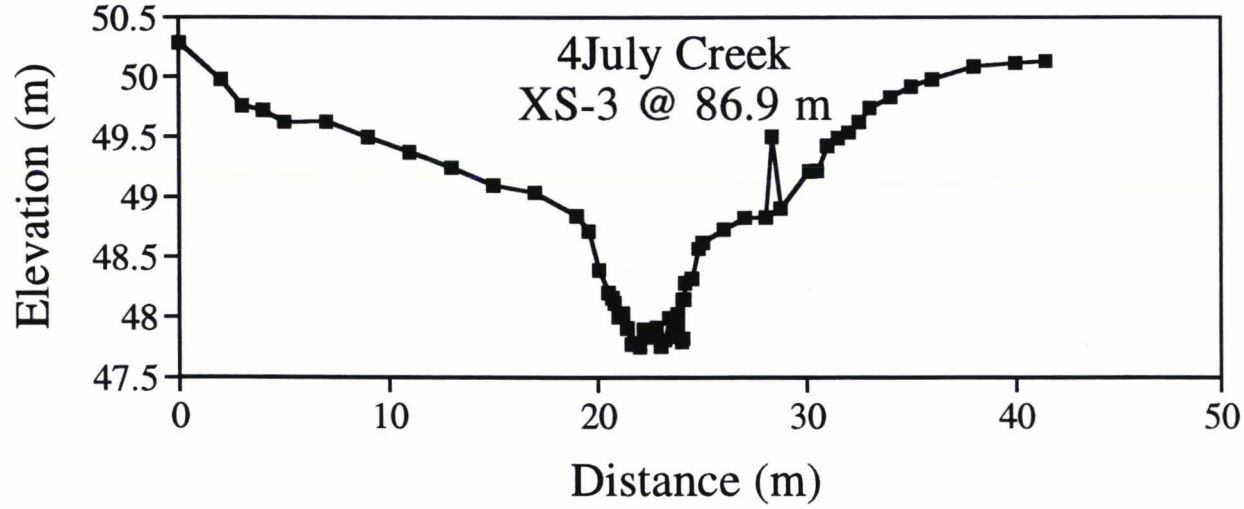

Little Slate Creek
XS-2 @ 159 m
Elevation (m)
49.5
49
48.5
48
47.5
47
-5
0
5
10
15
20
Distance (m)

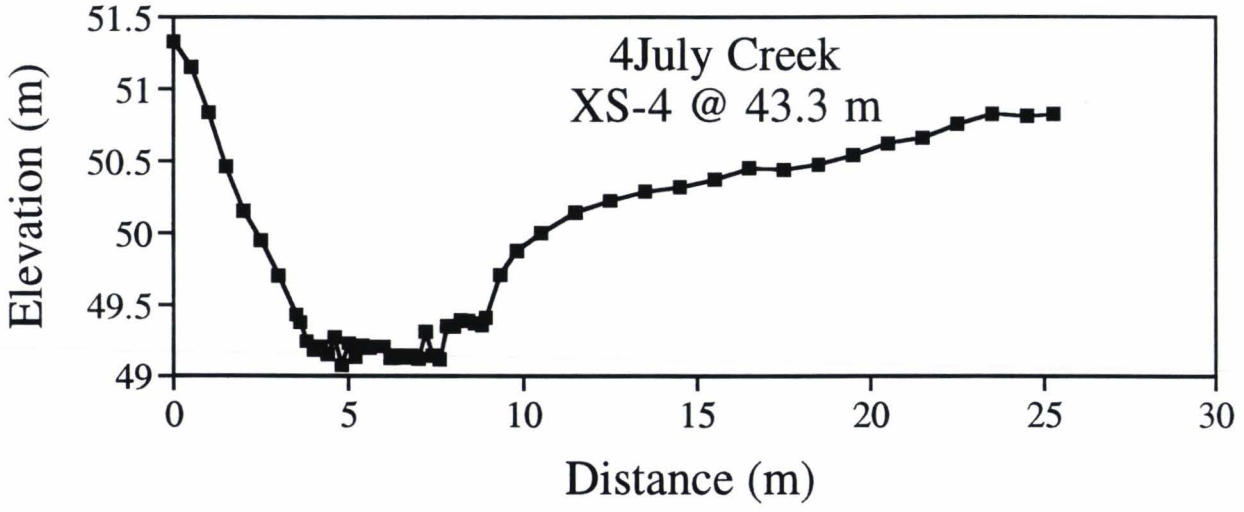

Little Slate Creek
XS-3 @ 94.7 m
Elevation (m)
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
Distance (m)

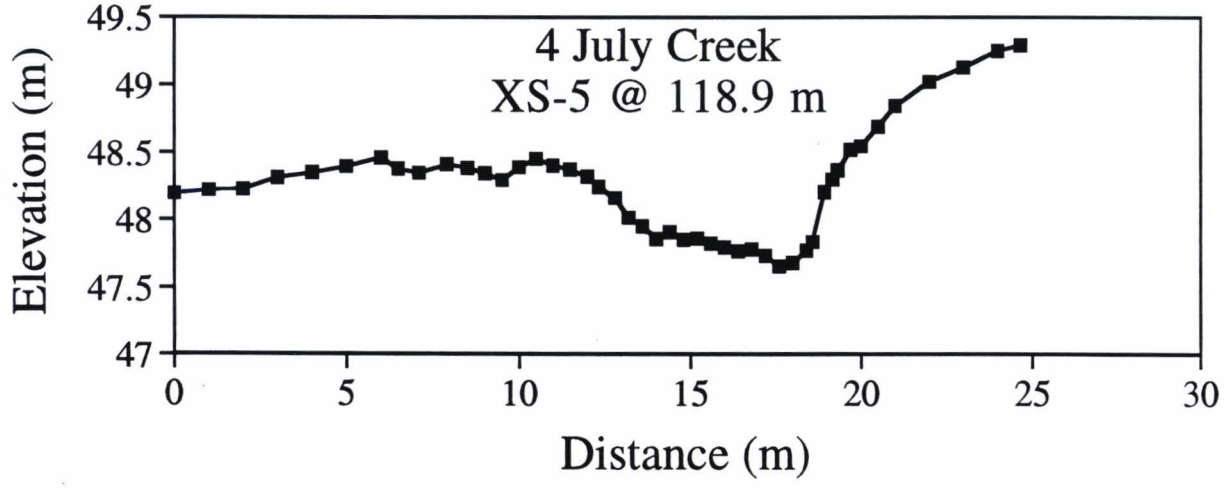

Fish Creek
XS-4 @ 20.1 m
Elevation (m)
101.5
101
100.5
100
99.5
99
98.5
0
5
10
15
20
25
30
Distance (m)

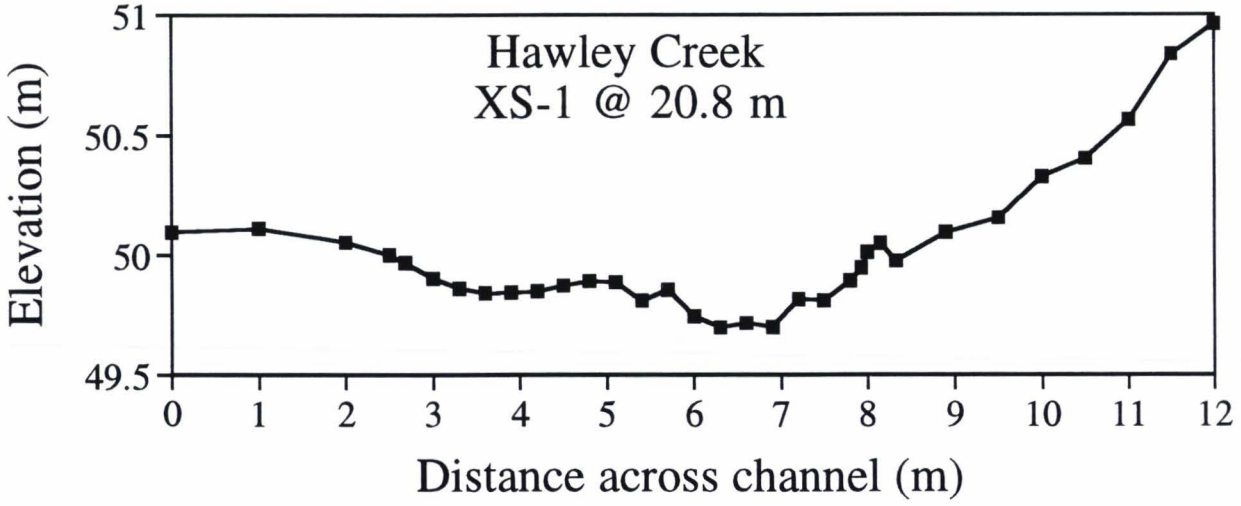

4July Creek
XS-1 @ 165.6 m
Elevation (m)
49
48.5
48
47.5
47
46.5
46
0
10
20
30
40
50
Distance (m)

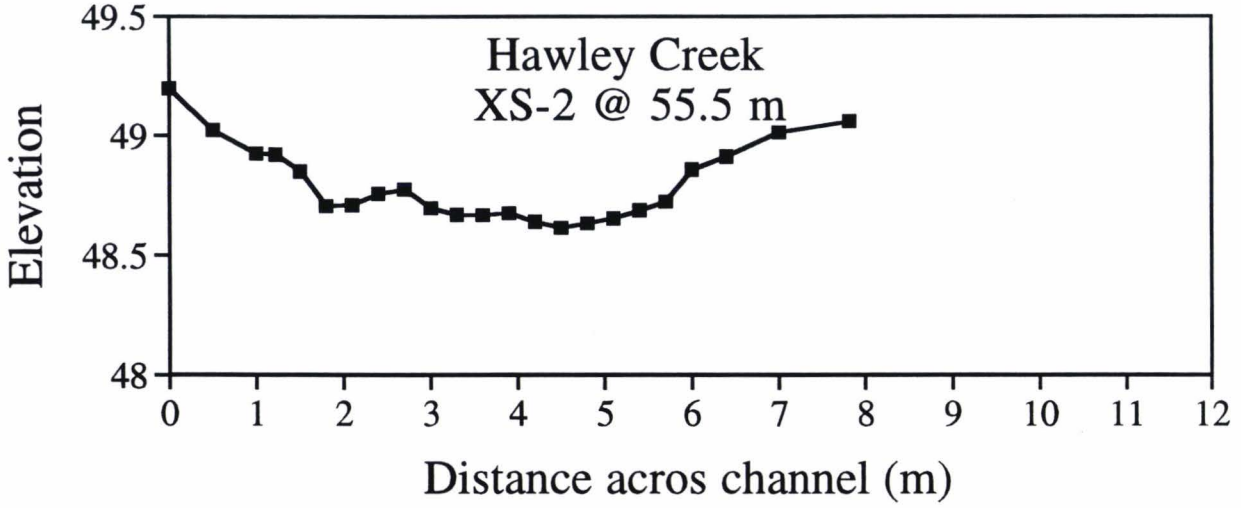

4July Creek
XS-2 @ 104.8 m
Elevation (m)
50.5
50
49.5
49
48.5
48
47.5
0
10
20
30
40
50
Distance (m)

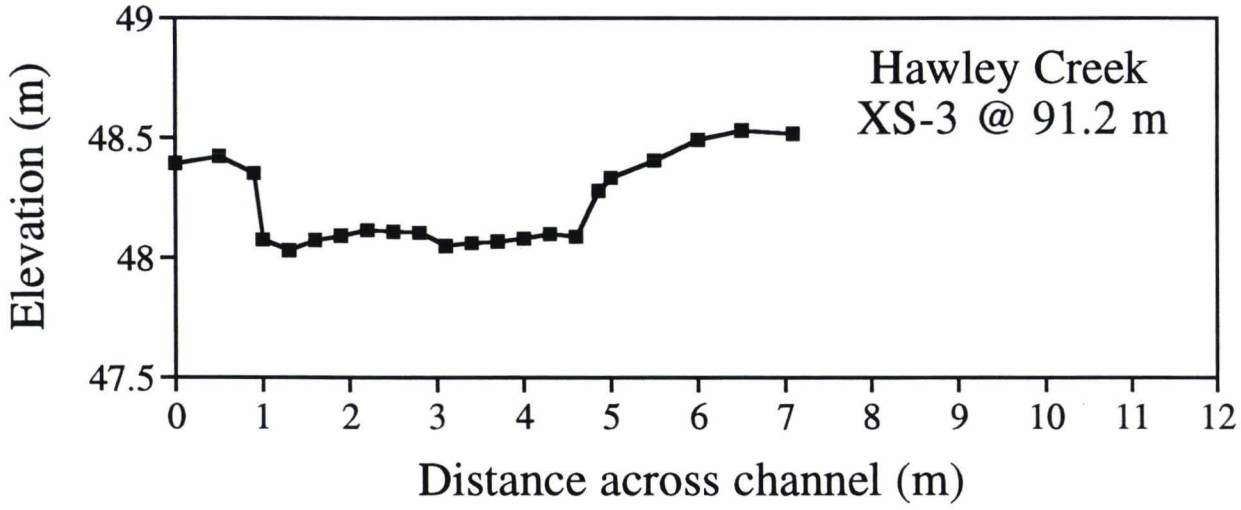

4July Creek
XS-3 @ 86.9 m
Elevation (m)
50.5
50
49.5
49
48.5
48
47.5
0
10
20
30
40
50
Distance (m)

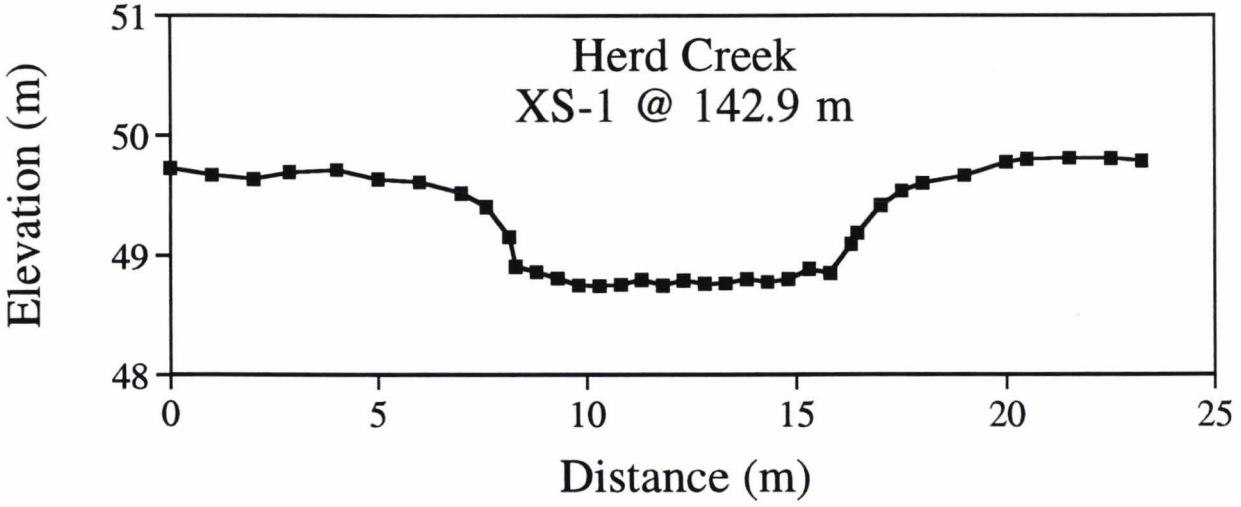

4July Creek
XS-4 @ 43.3 m
Elevation (m)
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
30
Distance (m)

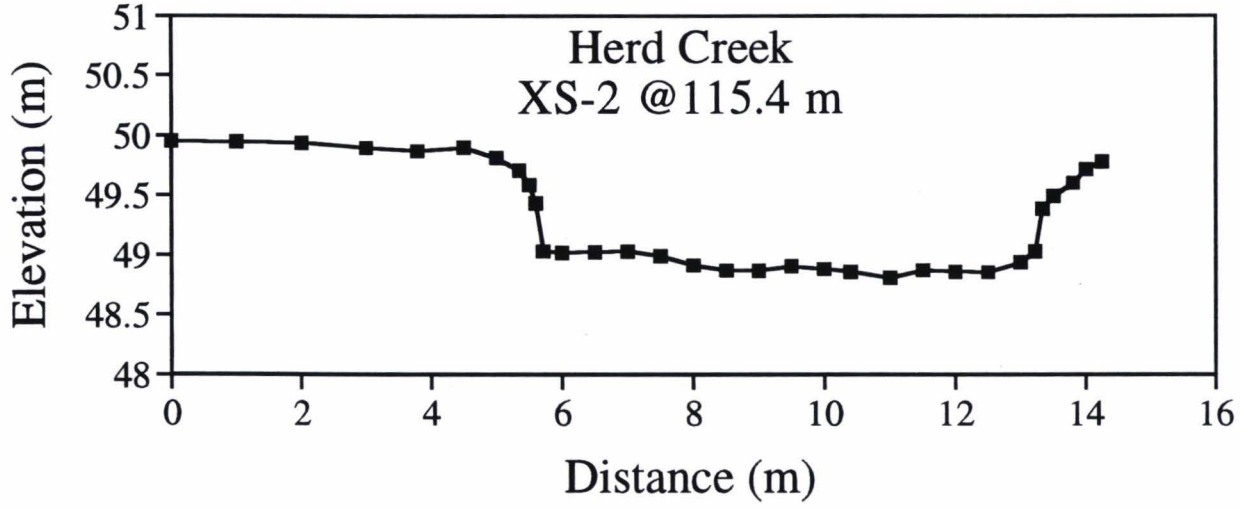

4 July Creek
XS-5 @ 118.9 m
Elevation (m)
49.5
49
48.5
48
47.5
47
0
5
10
15
20
25
30
Distance (m)

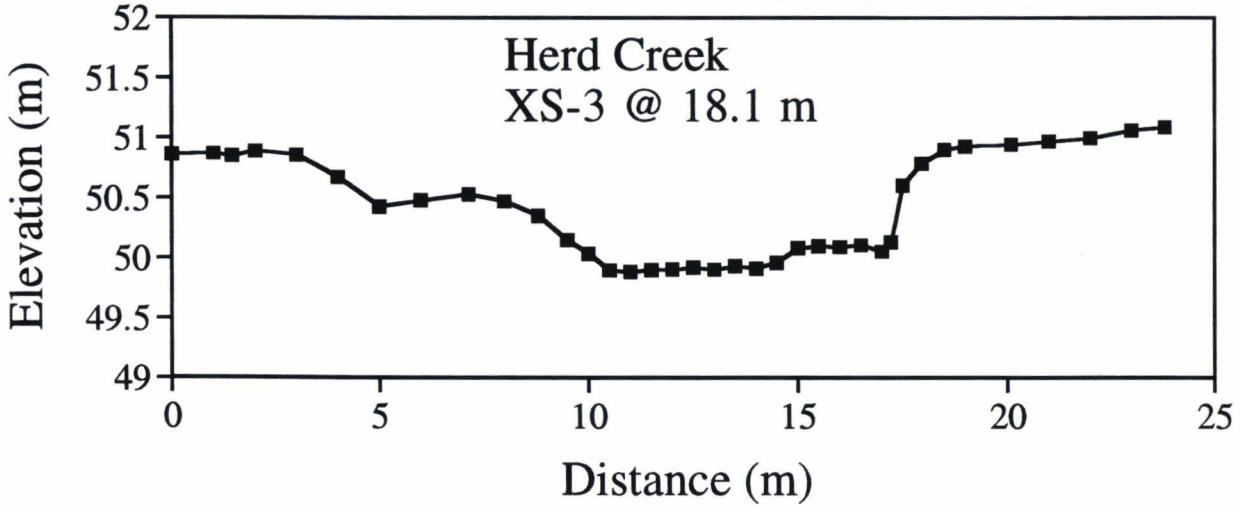

Hawley Creek
XS-1 @ 20.8 m
Elevation (m)
51
50.5
50
49.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance across channel (m)

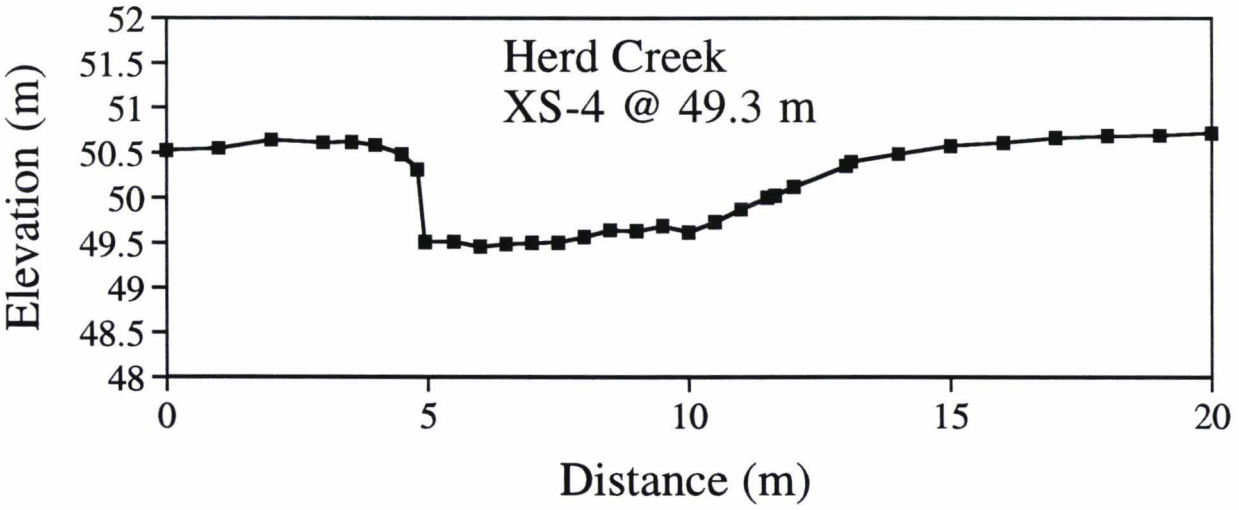

Hawley Creek
XS-2 @ 55.5 m
Elevation
49.5
49
48.5
48
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance acros channel (m)

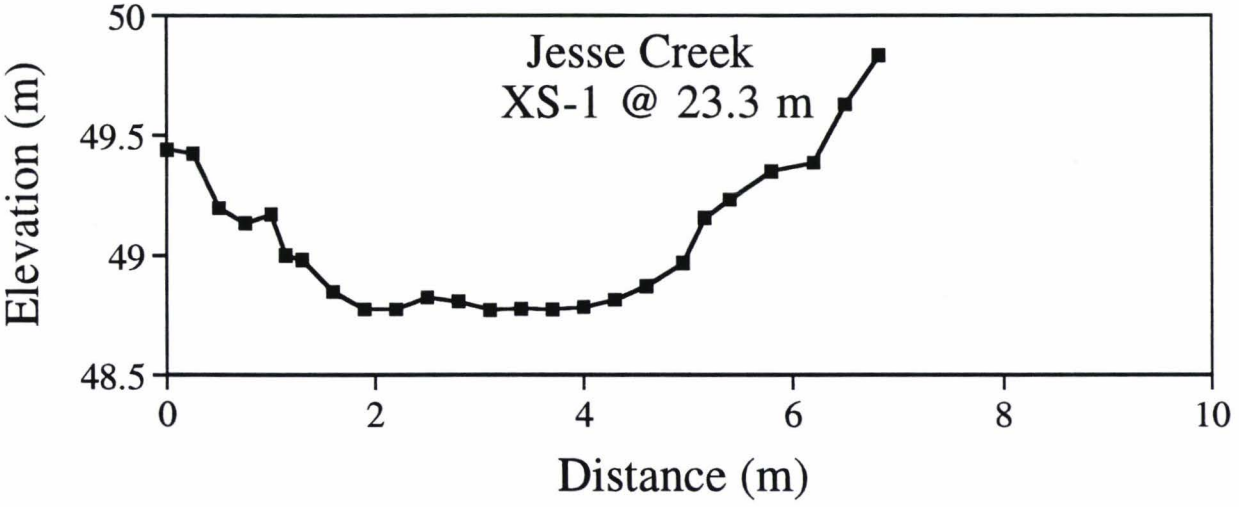

Hawley Creek
XS-3 @ 91.2 m
Elevation (m)
49
48.5
48
47.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance across channel (m)

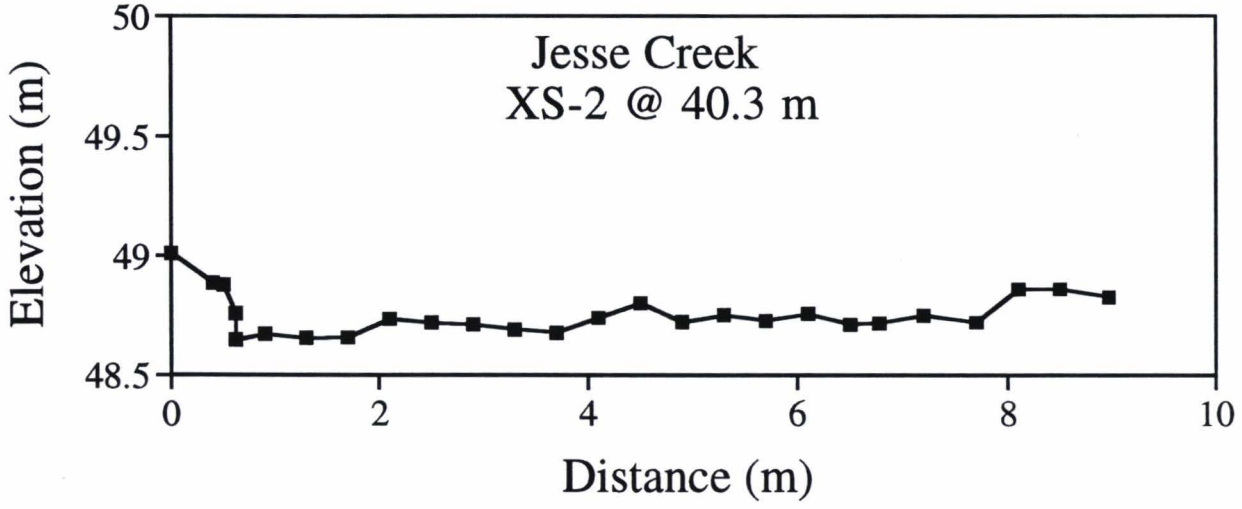

Herd Creek
XS-1 @ 142.9 m
Elevation (m)
51
50
49
48
0
5
10
15
20
25
Distance (m)

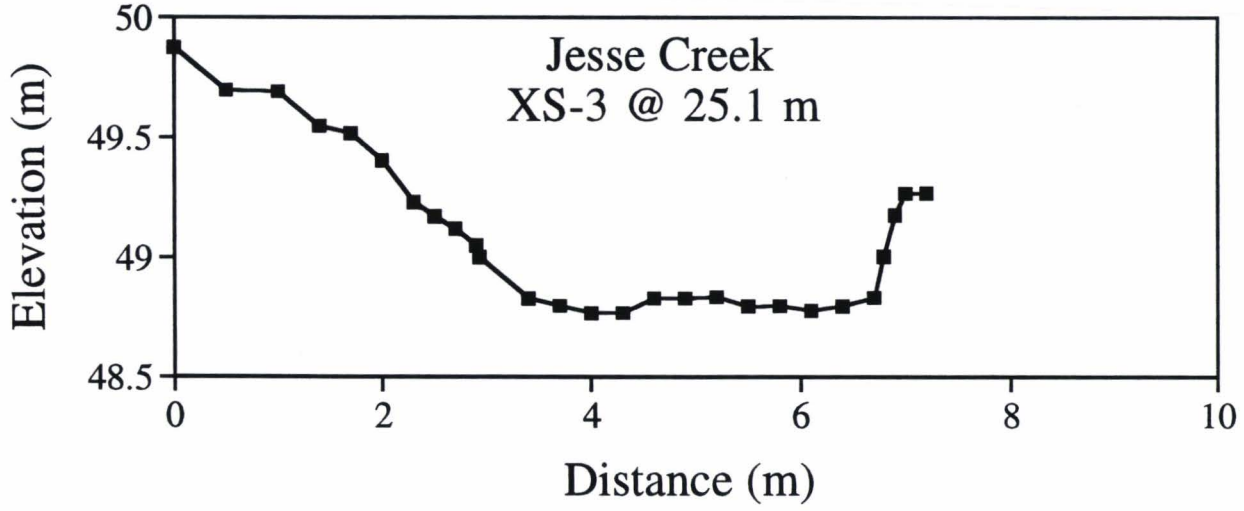

Herd Creek
XS-2 @115.4 m
Elevation (m)
51
50.5
50
49.5
49
48.5
48
0
2
4
6
8
10
12
14
16
Distance (m)

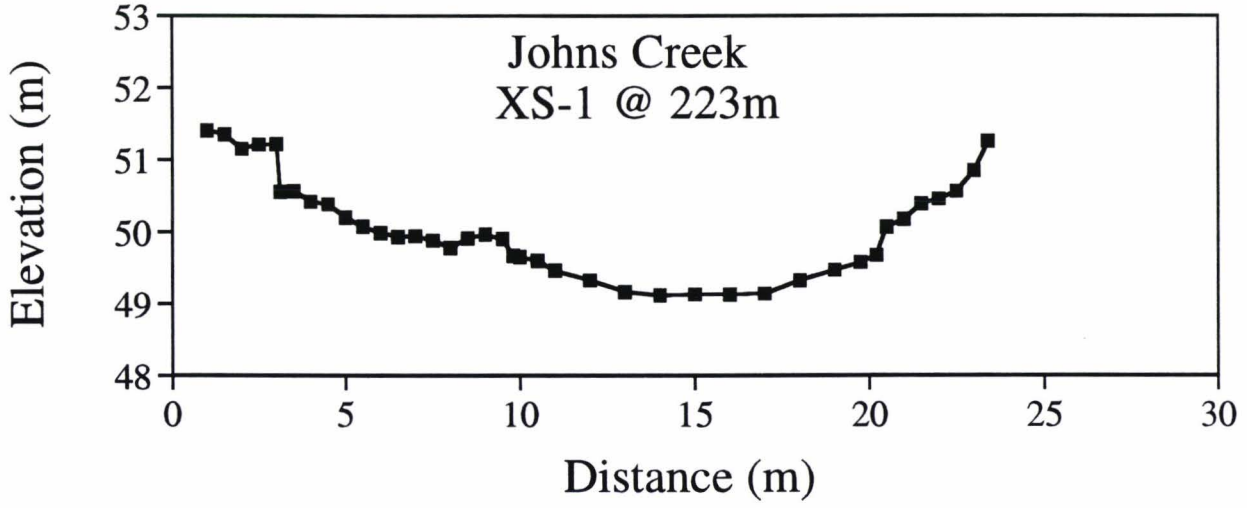

Herd Creek
XS-3 @ 18.1 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
Distance (m)

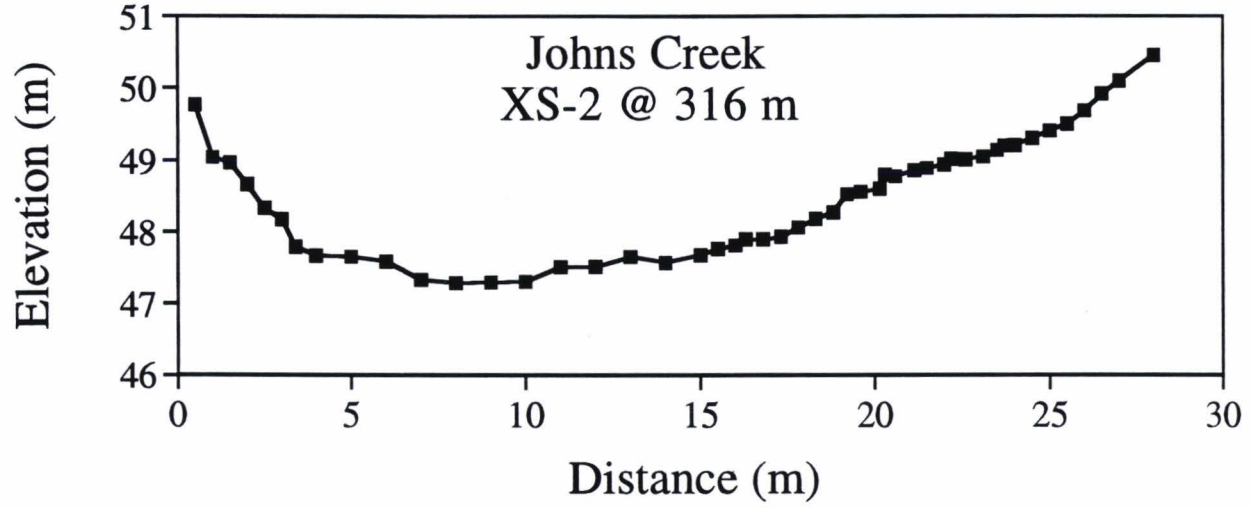

Herd Creek
XS-4 @ 49.3 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
48.5
48
0
5
10
15
20
Distance (m)

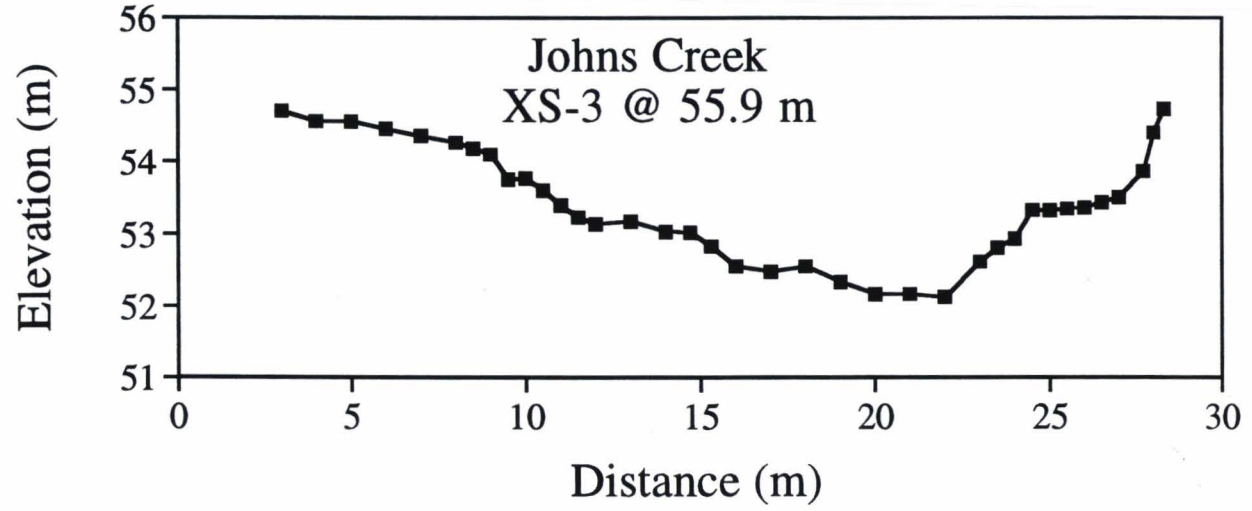

Jesse Creek
XS-1 @ 23.3 m
Elevation (m)
50
49.5
49
48.5
0
2
4
6
8
10
Distance (m)

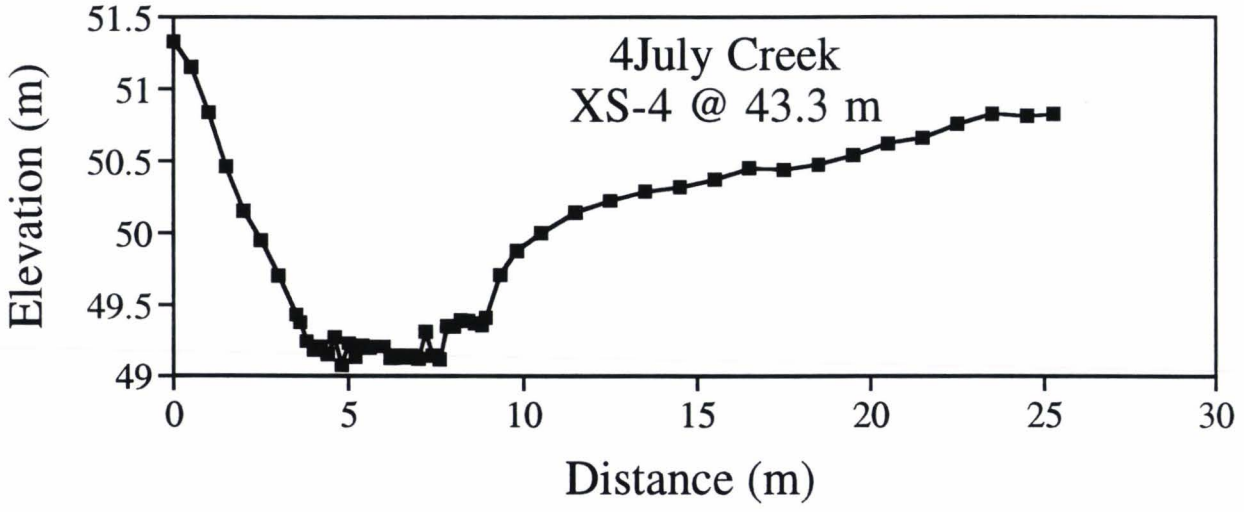

Jesse Creek
XS-2 @ 40.3 m
Elevation (m)
50
49.5
49
48.5
0
2
4
6
8
10
Distance (m)

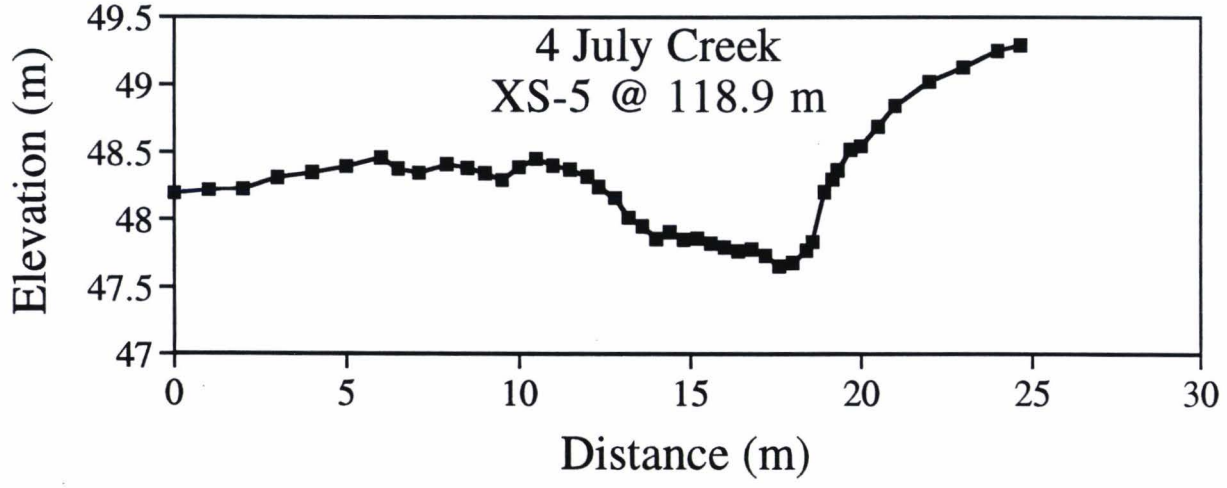

Jesse Creek
XS-3 @ 25.1 m
Elevation (m)
50
49.5
49
48.5
0
2
4
6
8
10
Distance (m)

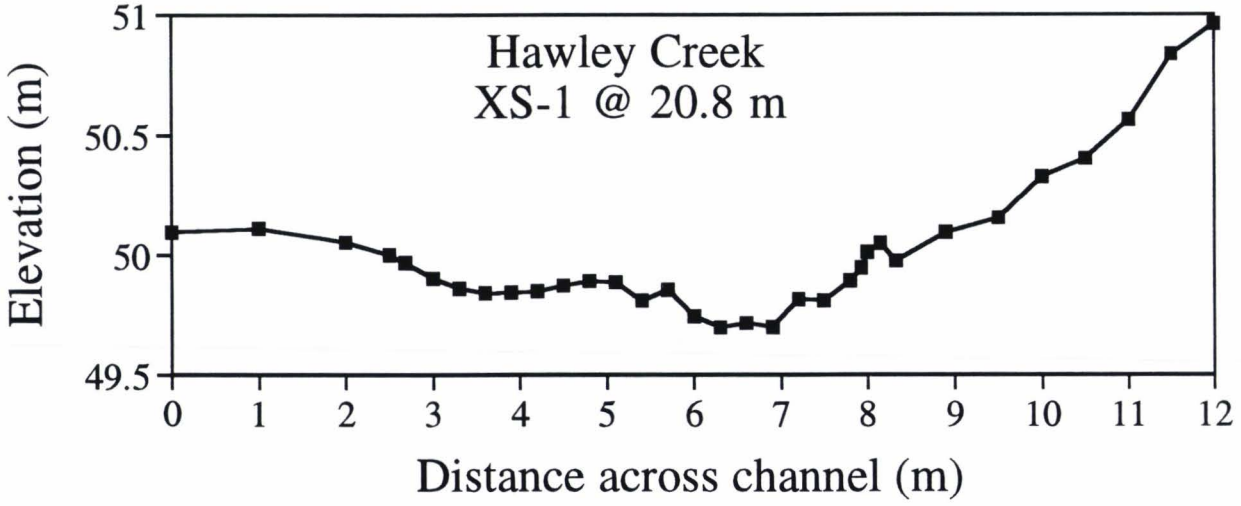

Johns Creek
XS-1 @ 223m
Elevation (m)
Distance (m)
53
52
51
50
49
48
0
5
10
15
20
25
30

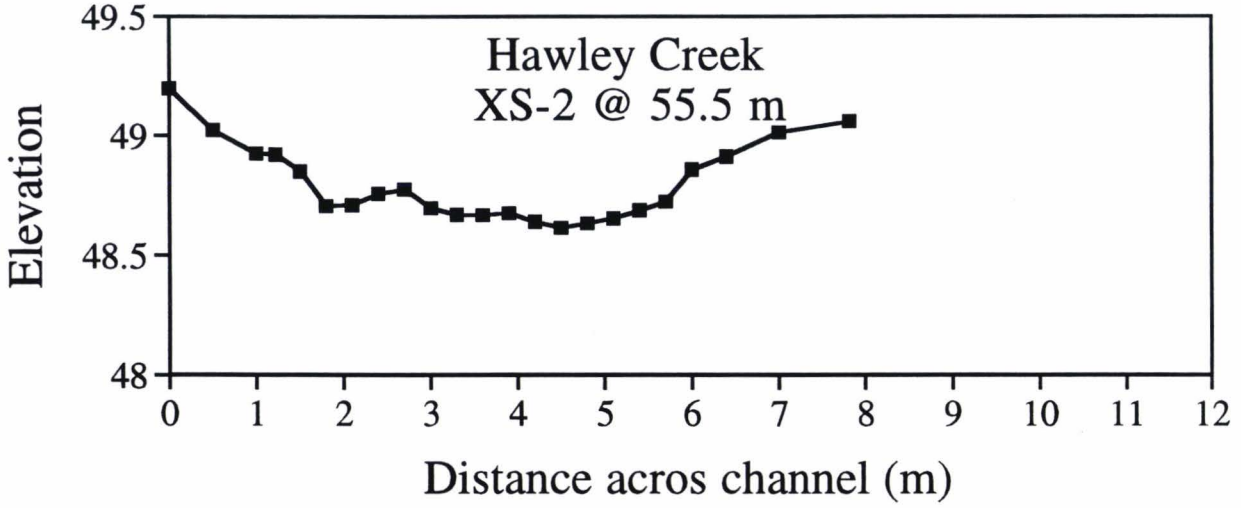

Johns Creek
XS-2 @ 316 m
Elevation (m)
Distance (m)
51
50
49
48
47
46
0
5
10
15
20
25
30

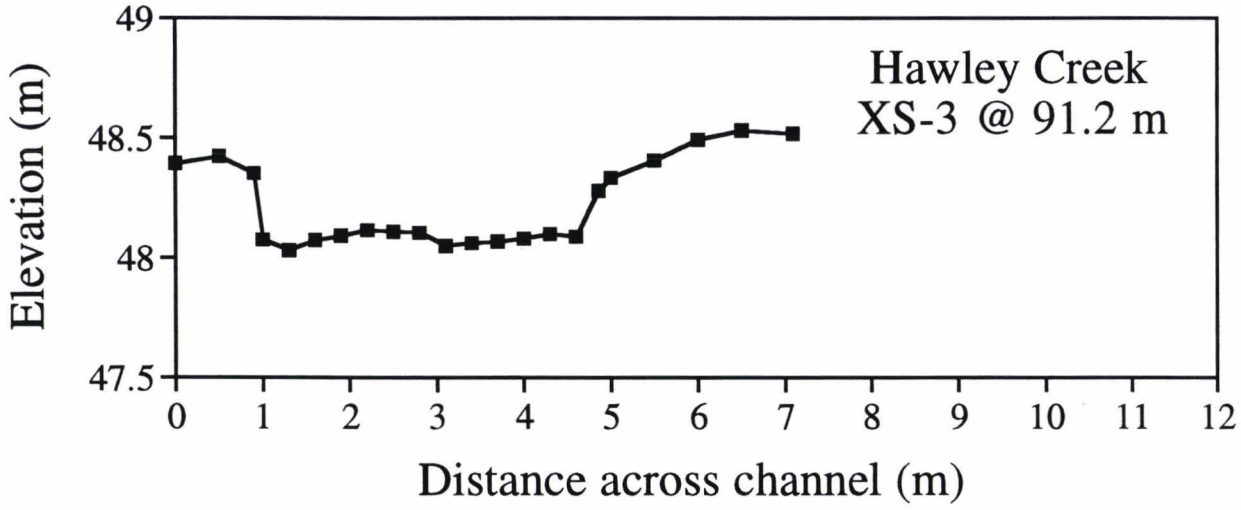

Johns Creek
XS-3 @ 55.9 m
Elevation (m)
Distance (m)
56
55
54
53
52
51
0
5
10
15
20
25
30

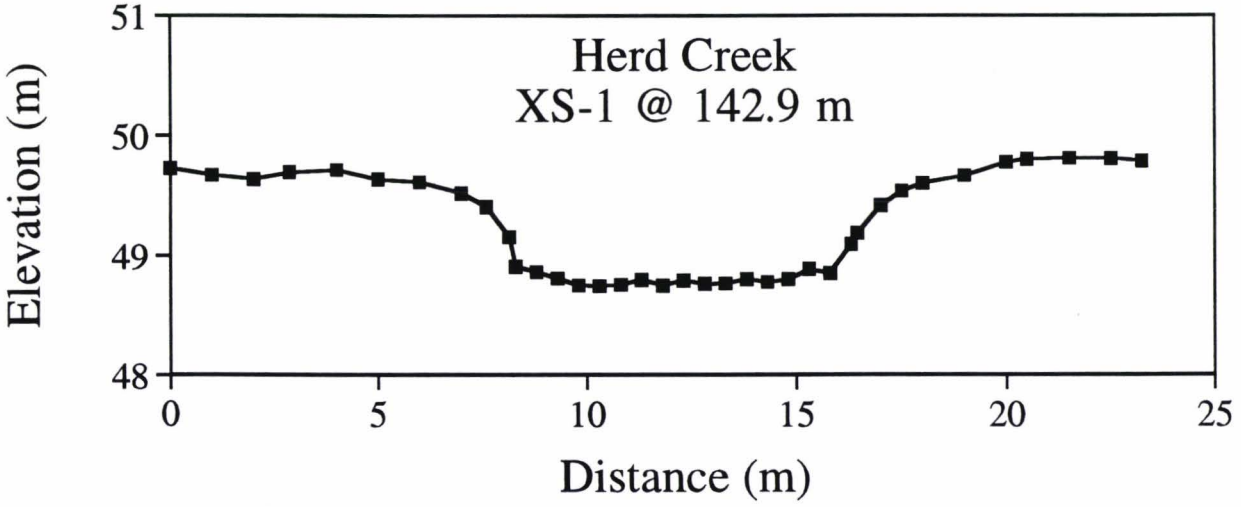

4July Creek
XS-4 @ 43.3 m
Elevation (m)
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
30
Distance (m)

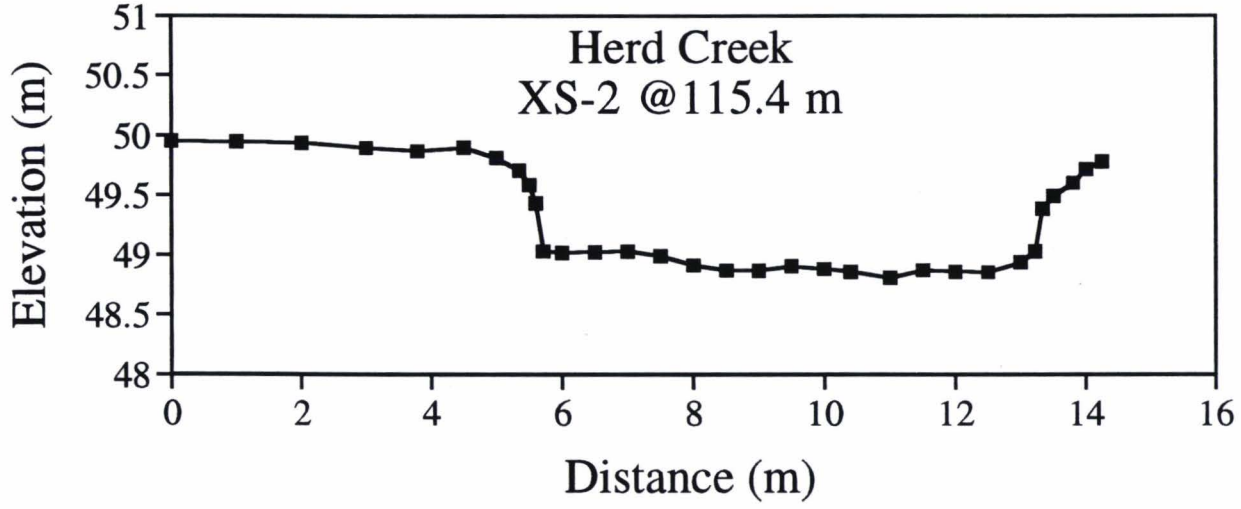

4 July Creek
XS-5 @ 118.9 m
Elevation (m)
49.5
49
48.5
48
47.5
47
0
5
10
15
20
25
30
Distance (m)

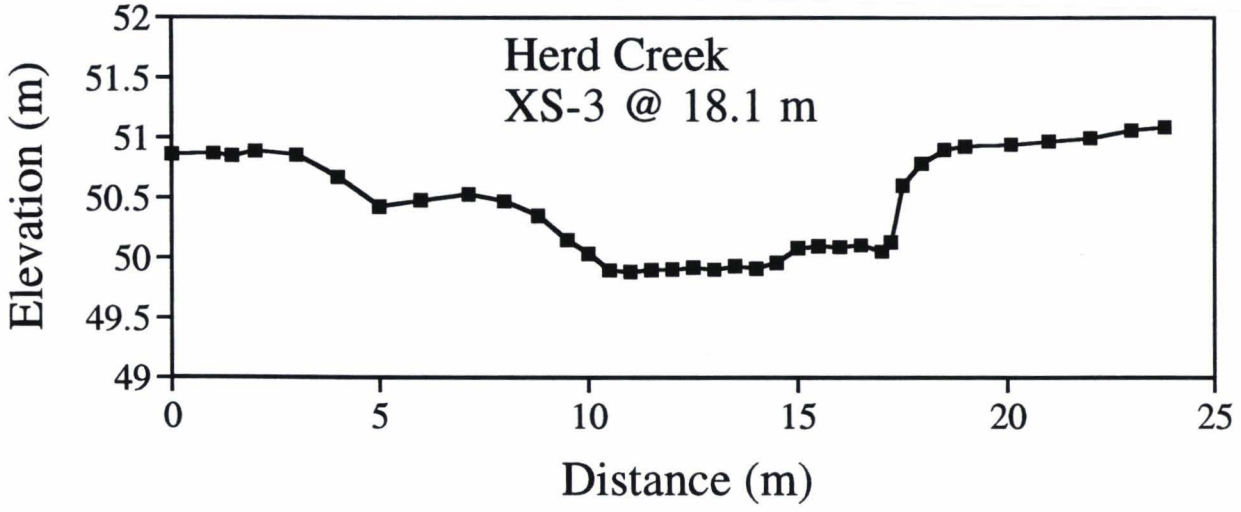

Hawley Creek
XS-1 @ 20.8 m
Elevation (m)
51
50.5
50
49.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance across channel (m)

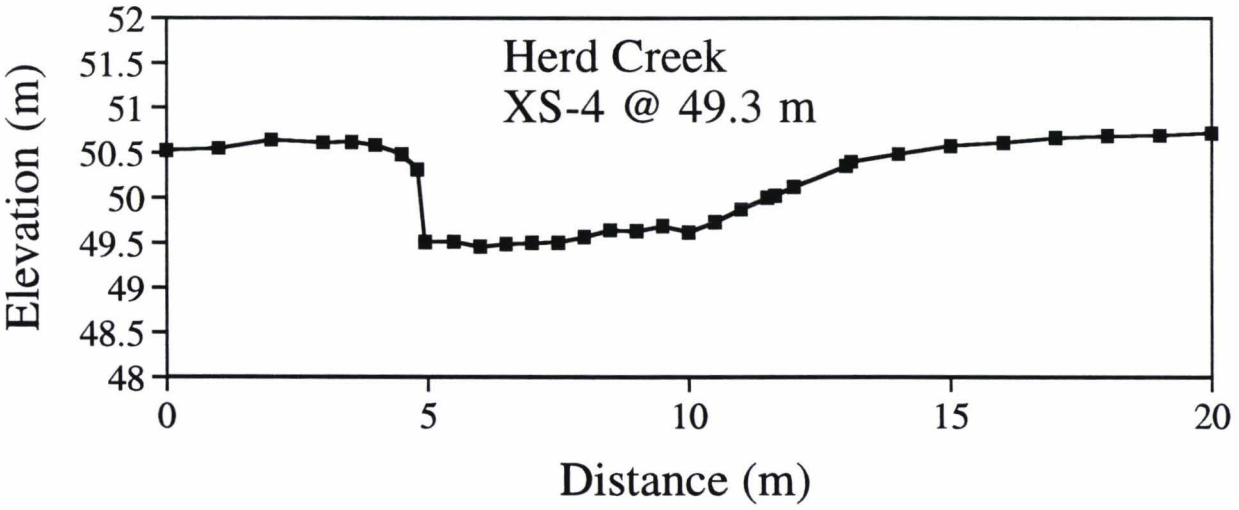

Hawley Creek
XS-2 @ 55.5 m
Elevation
49.5
49
48.5
48
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance acros channel (m)

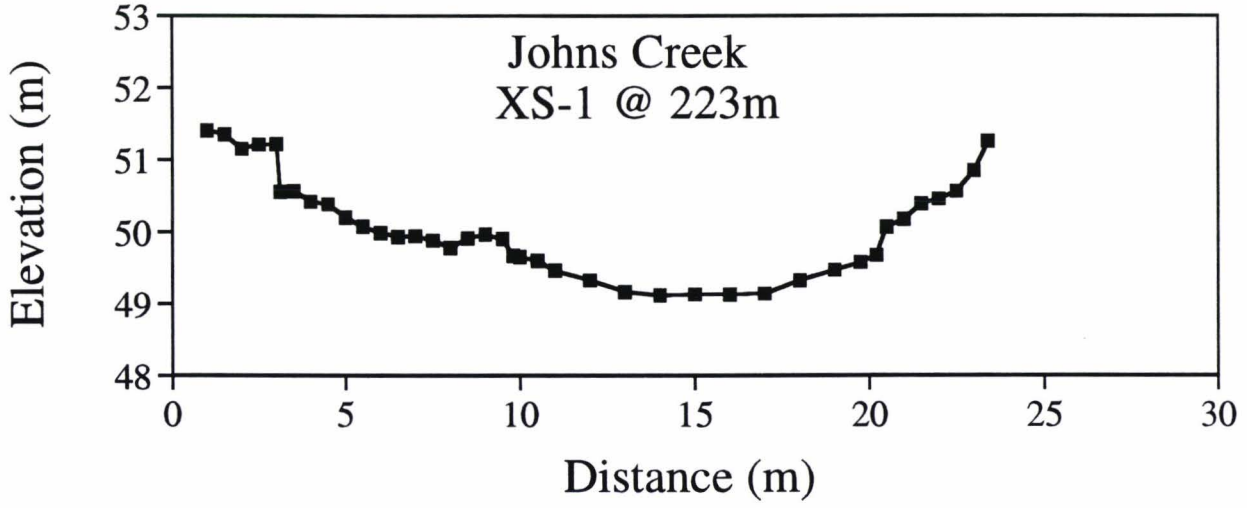

Hawley Creek
XS-3 @ 91.2 m
Elevation (m)
49
48.5
48
47.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Distance across channel (m)

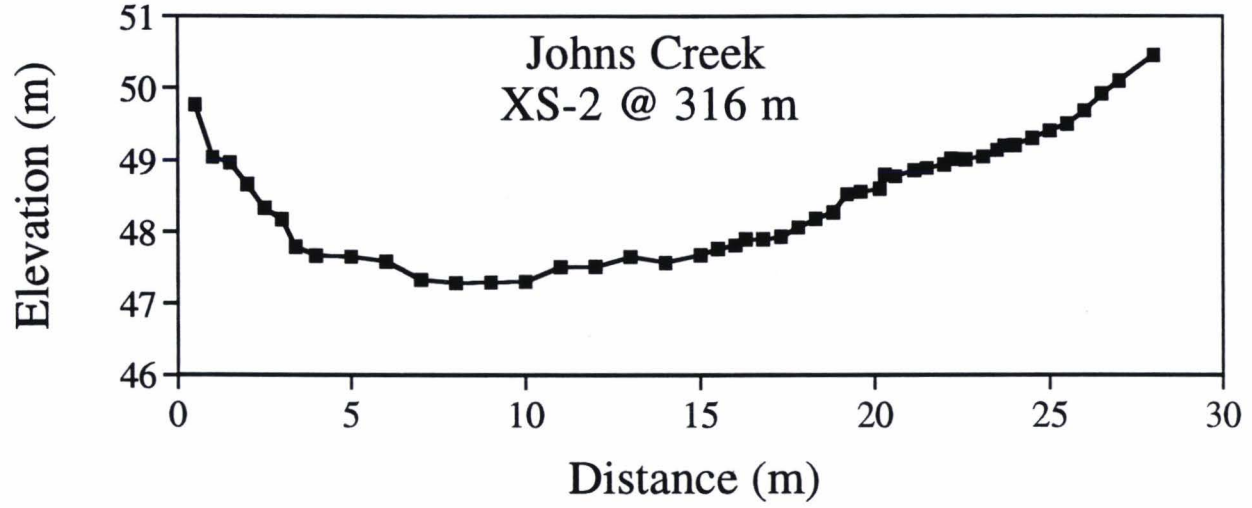

Herd Creek
XS-1 @ 142.9 m
Elevation (m)
51
50
49
48
0
5
10
15
20
25
Distance (m)

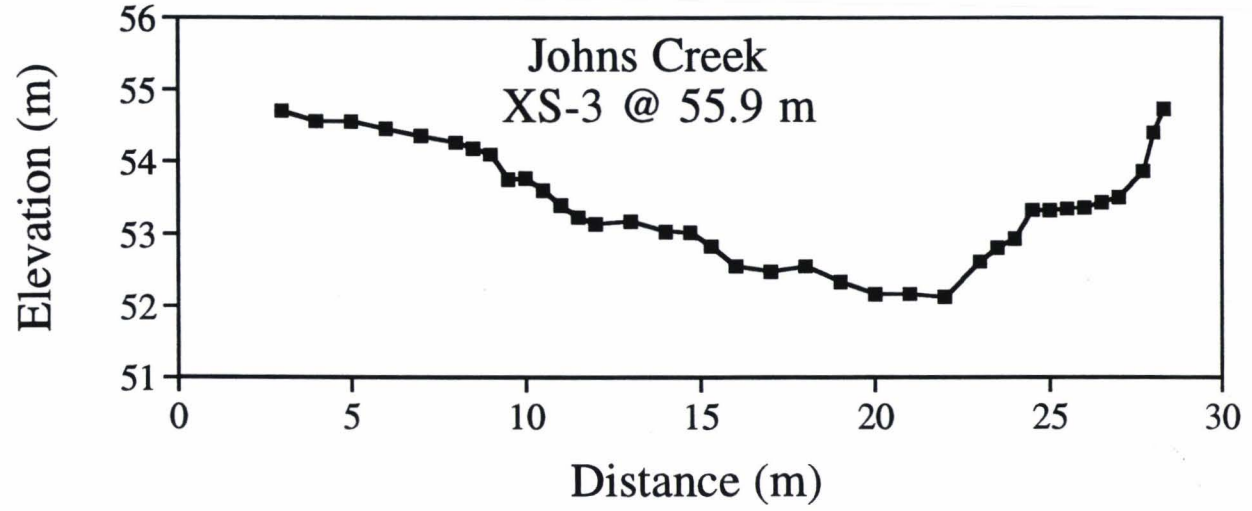

Herd Creek
XS-2 @115.4 m
Elevation (m)
51
50.5
50
49.5
49
48.5
48
0
2
4
6
8
10
12
14
16
Distance (m)

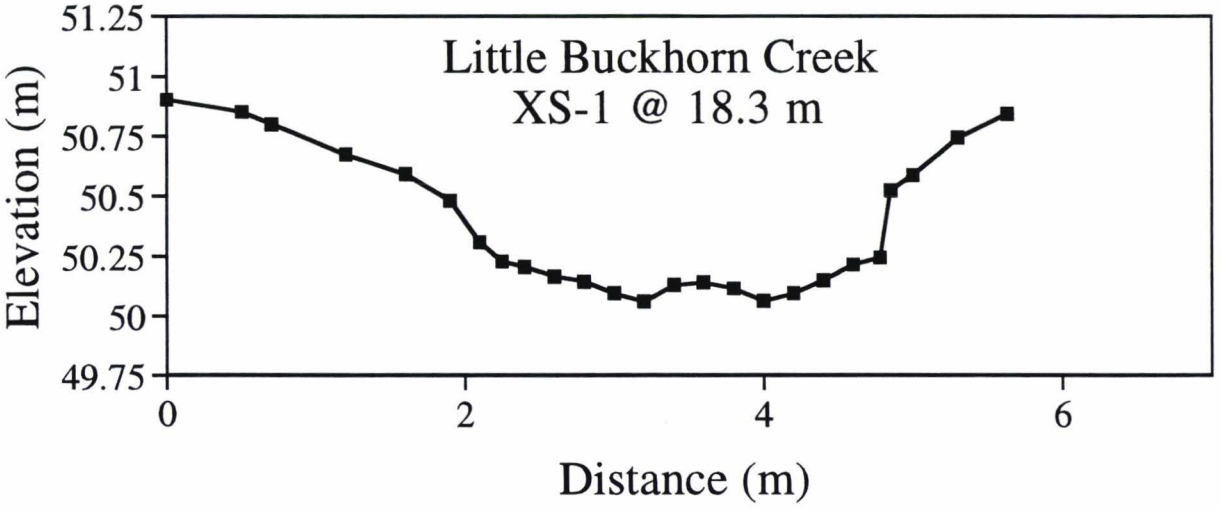

Herd Creek
XS-3 @ 18.1 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
Distance (m)

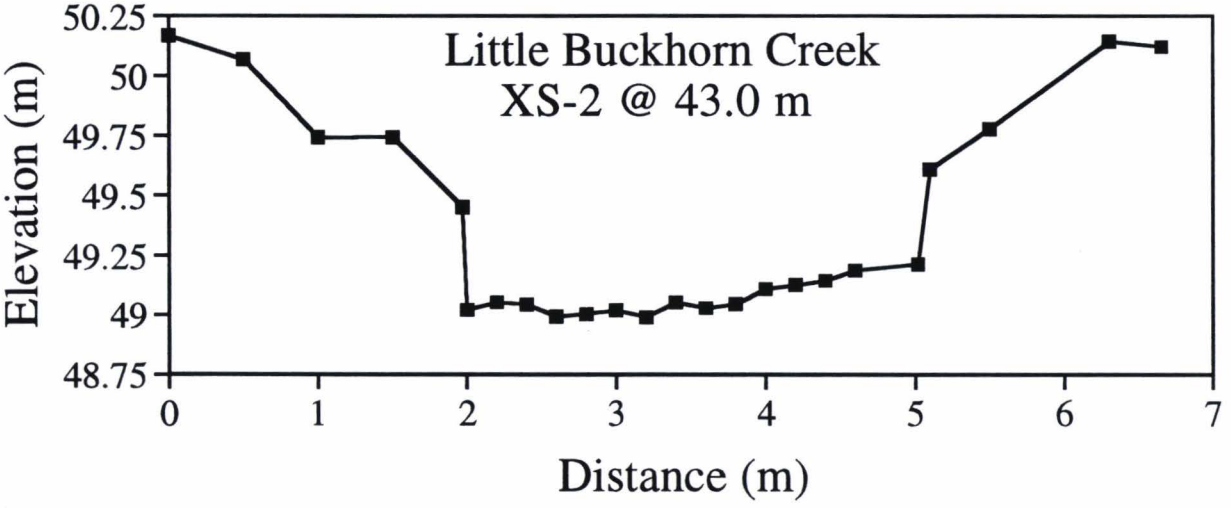

Herd Creek
XS-4 @ 49.3 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
48.5
48
0
5
10
15
20
Distance (m)

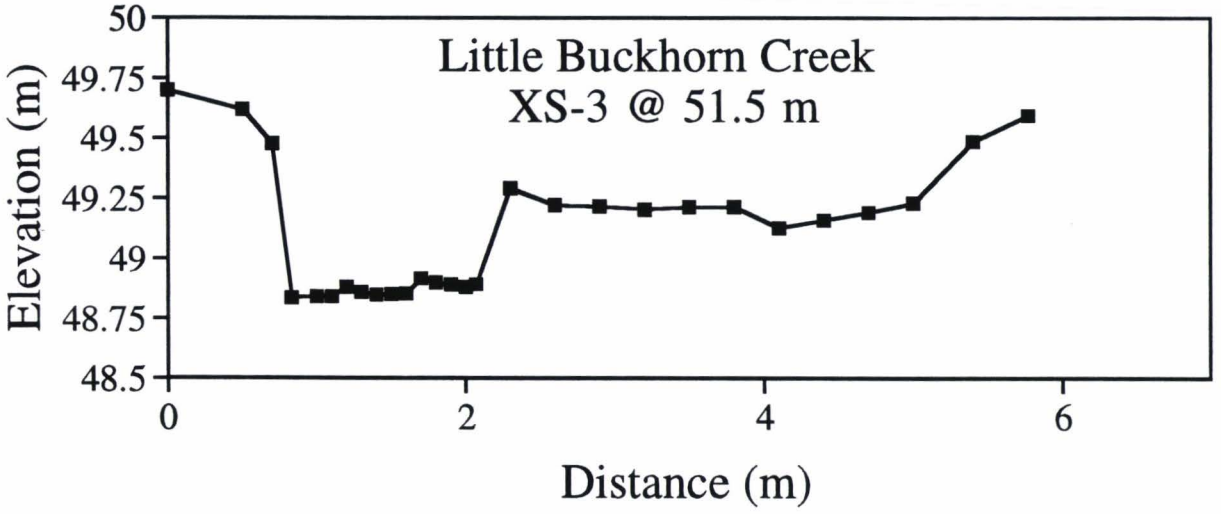

Johns Creek
XS-1 @ 223m
Elevation (m)
Distance (m)
53
52
51
50
49
48
0
5
10
15
20
25
30

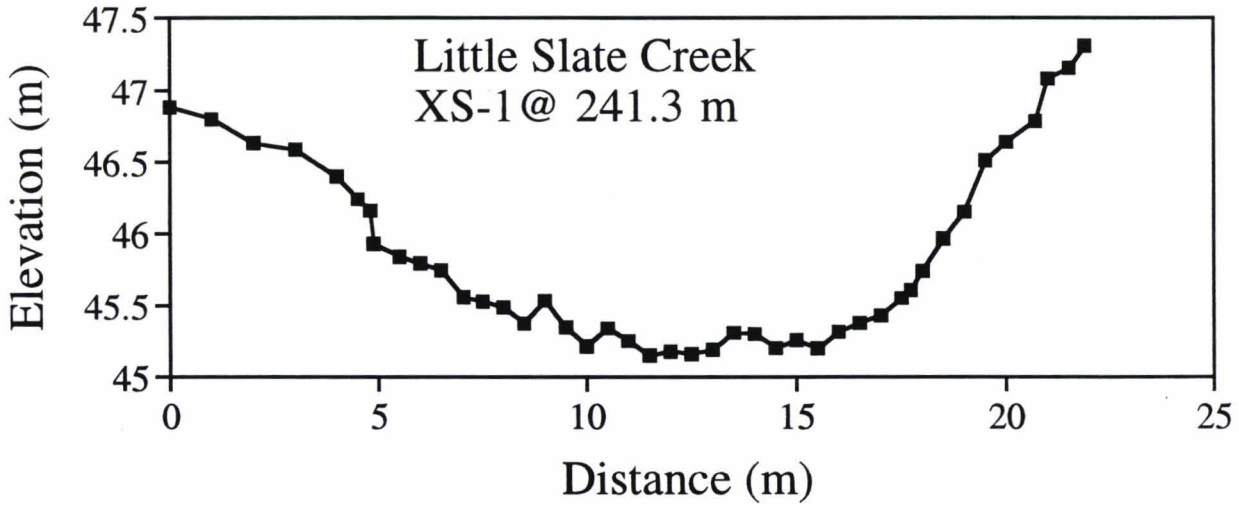

Johns Creek
XS-2 @ 316 m
Elevation (m)
Distance (m)
51
50
49
48
47
46
0
5
10
15
20
25
30

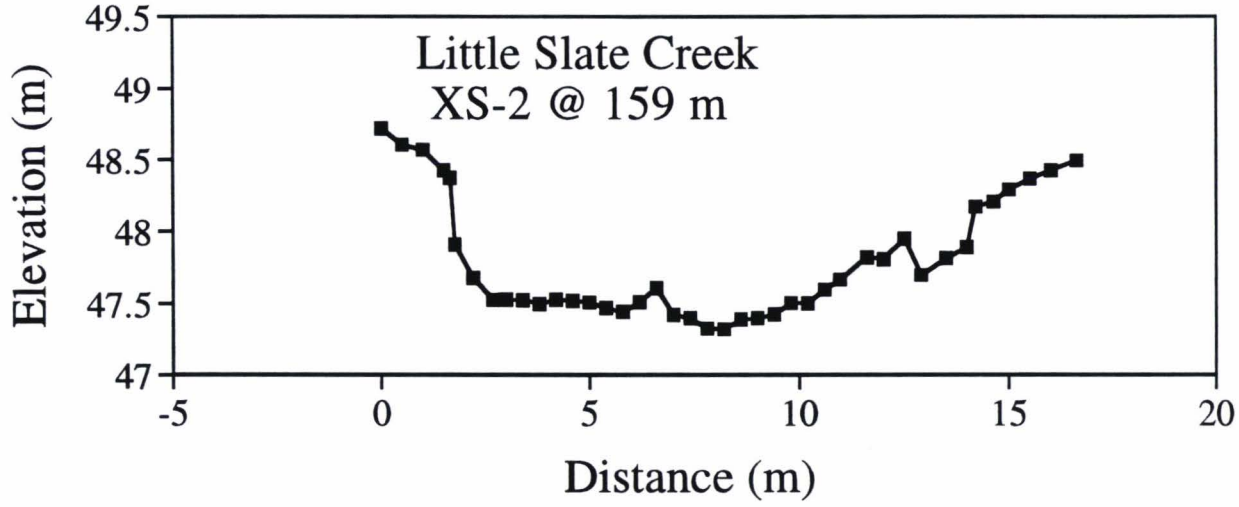

Johns Creek
XS-3 @ 55.9 m
Elevation (m)
Distance (m)
56
55
54
53
52
51
0
5
10
15
20
25
30

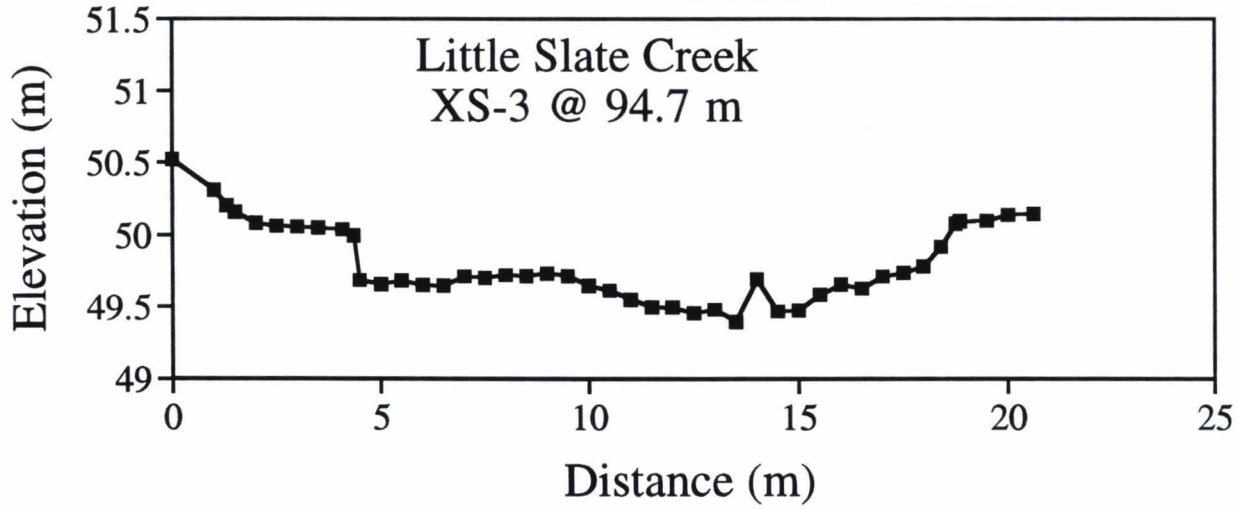

Little Buckhorn Creek
XS-1 @ 18.3 m
Elevation (m)
51.25
51
50.75
50.5
50.25
50
49.75
0
2
4
6
Distance (m)

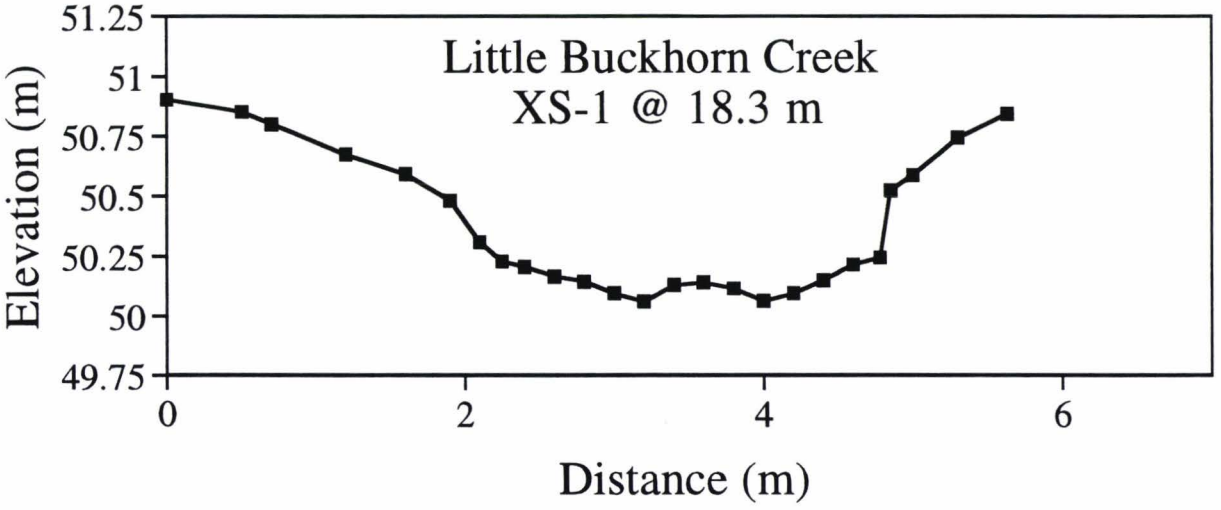

Little Buckhorn Creek
XS-2 @ 43.0 m
Elevation (m)
50.25
50
49.75
49.5
49.25
49
48.75
0
1
2
3
4
5
6
7
Distance (m)

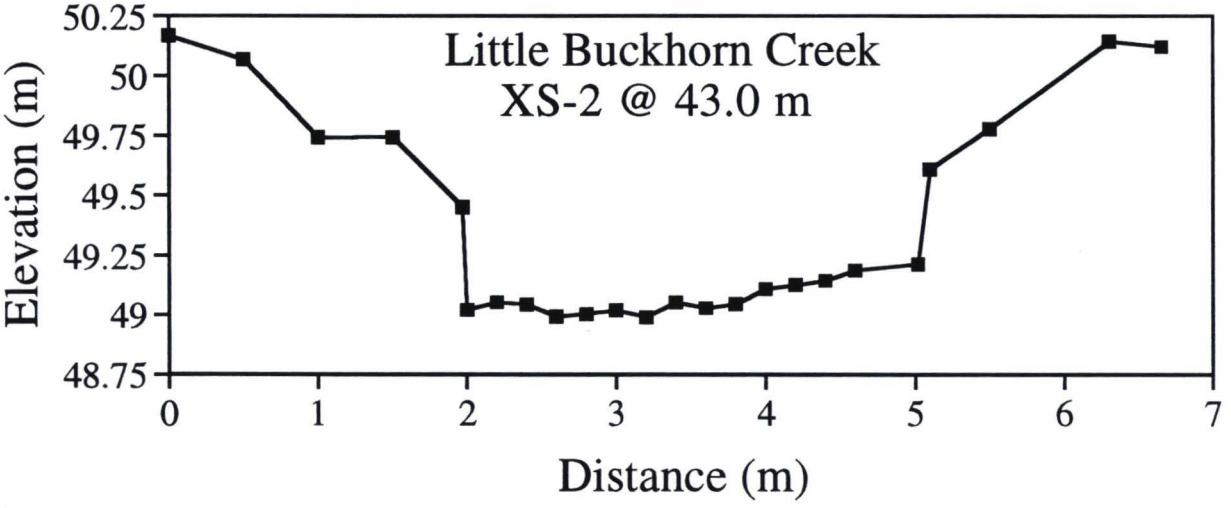

Little Buckhorn Creek
XS-3 @ 51.5 m
Elevation (m)
50
49.75
49.5
49.25
49
48.75
48.5
0
2
4
6
Distance (m)

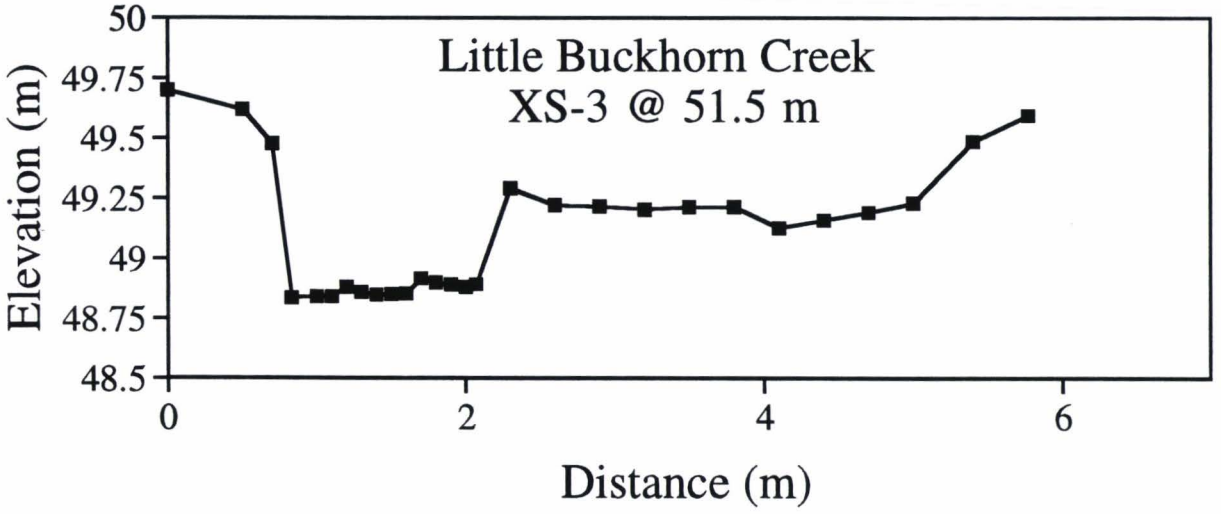

Little Slate Creek
XS-1@ 241.3 m
Elevation (m)
47.5
47
46.5
46
45.5
45
0
5
10
15
20
25
Distance (m)

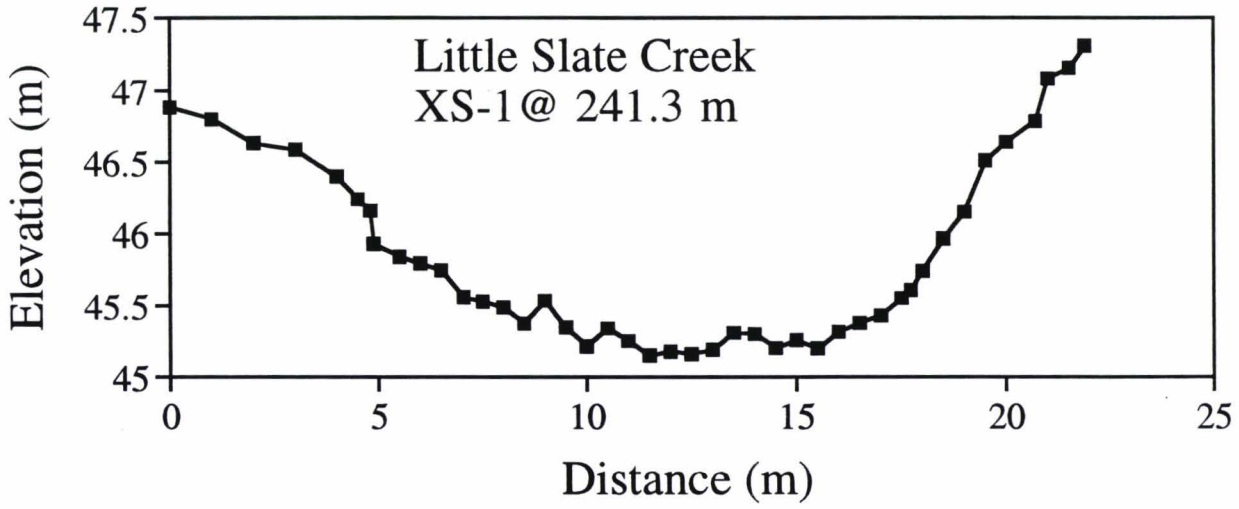

Little Slate Creek
XS-2 @ 159 m
Elevation (m)
49.5
49
48.5
48
47.5
47
-5
0
5
10
15
20
Distance (m)

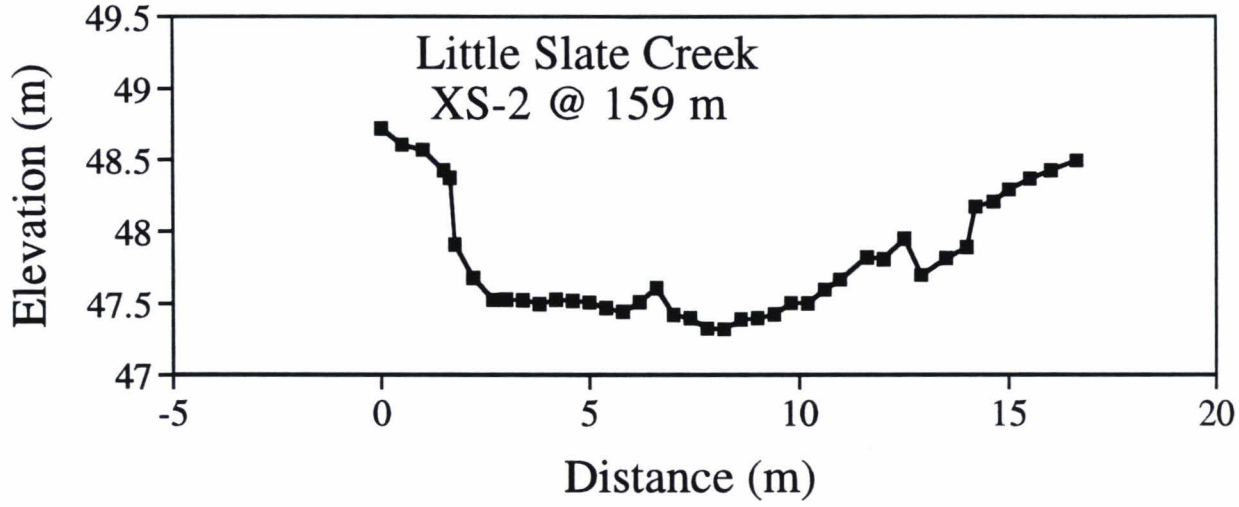

Little Slate Creek
XS-3 @ 94.7 m
Elevation (m)
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
Distance (m)

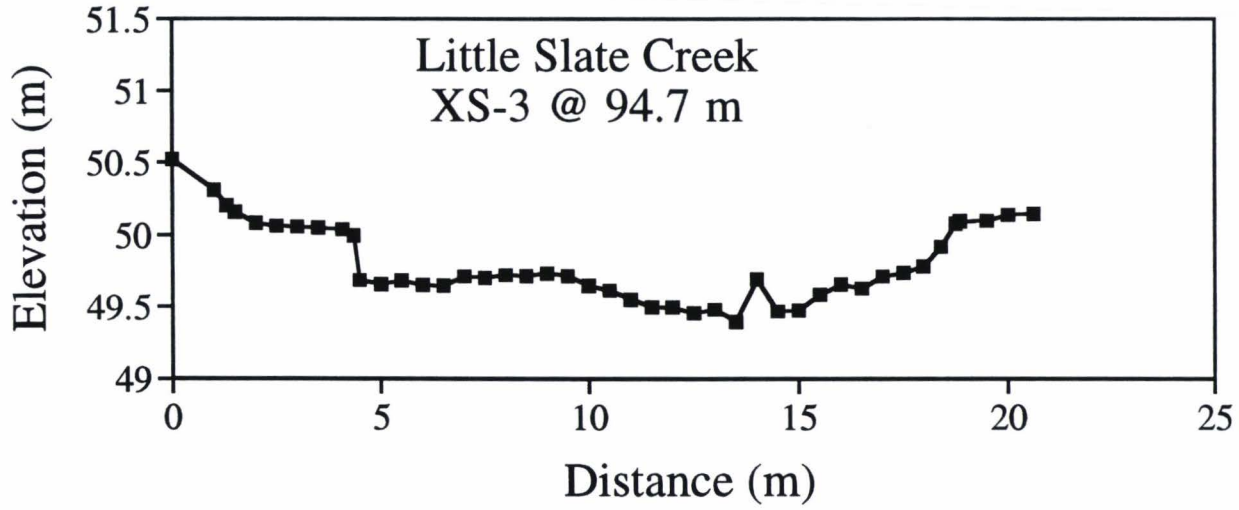

Little Buckhorn Creek
XS-1 @ 18.3 m
Elevation (m)
51.25
51
50.75
50.5
50.25
50
49.75
0
2
4
6
Distance (m)

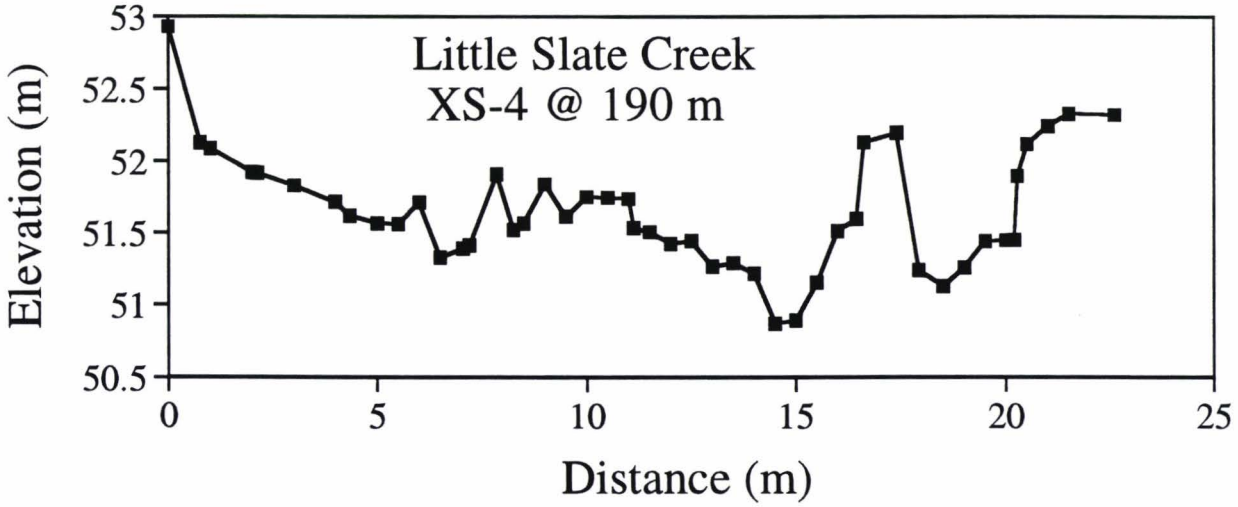

Little Buckhorn Creek
XS-2 @ 43.0 m
Elevation (m)
50.25
50
49.75
49.5
49.25
49
48.75
0
1
2
3
4
5
6
7
Distance (m)

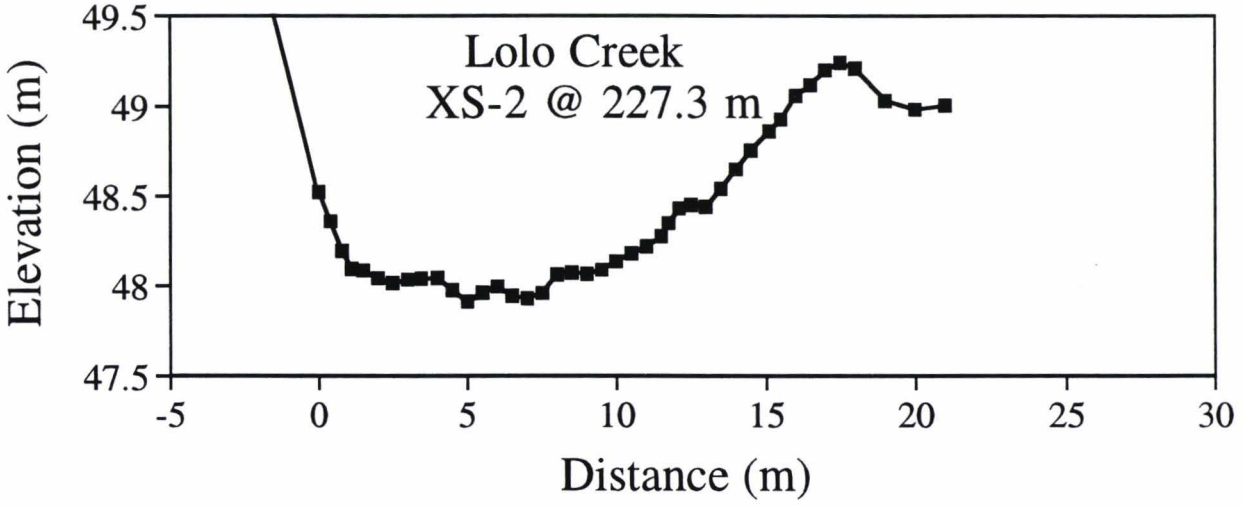

Little Buckhorn Creek
XS-3 @ 51.5 m
Elevation (m)
50
49.75
49.5
49.25
49
48.75
48.5
0
2
4
6
Distance (m)

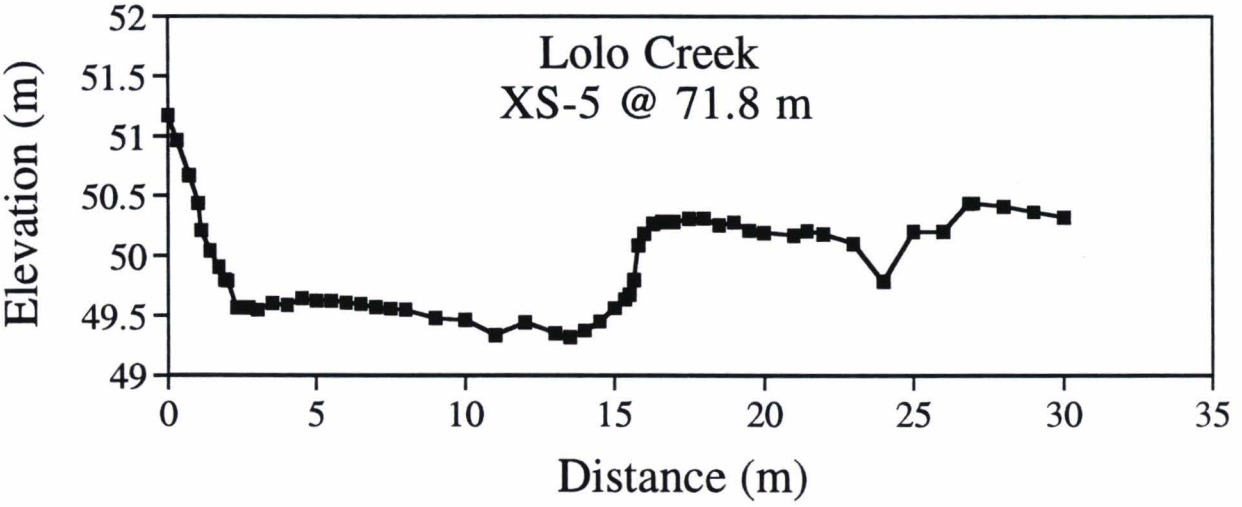

Little Slate Creek
XS-1@ 241.3 m
Elevation (m)
47.5
47
46.5
46
45.5
45
0
5
10
15
20
25
Distance (m)

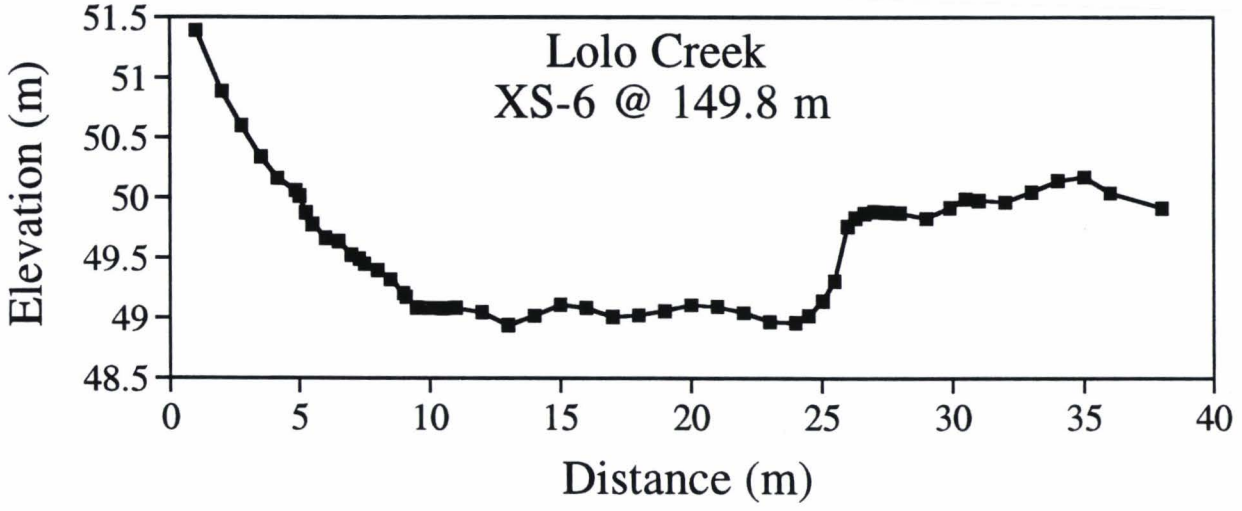

Little Slate Creek
XS-2 @ 159 m
Elevation (m)
49.5
49
48.5
48
47.5
47
-5
0
5
10
15
20
Distance (m)

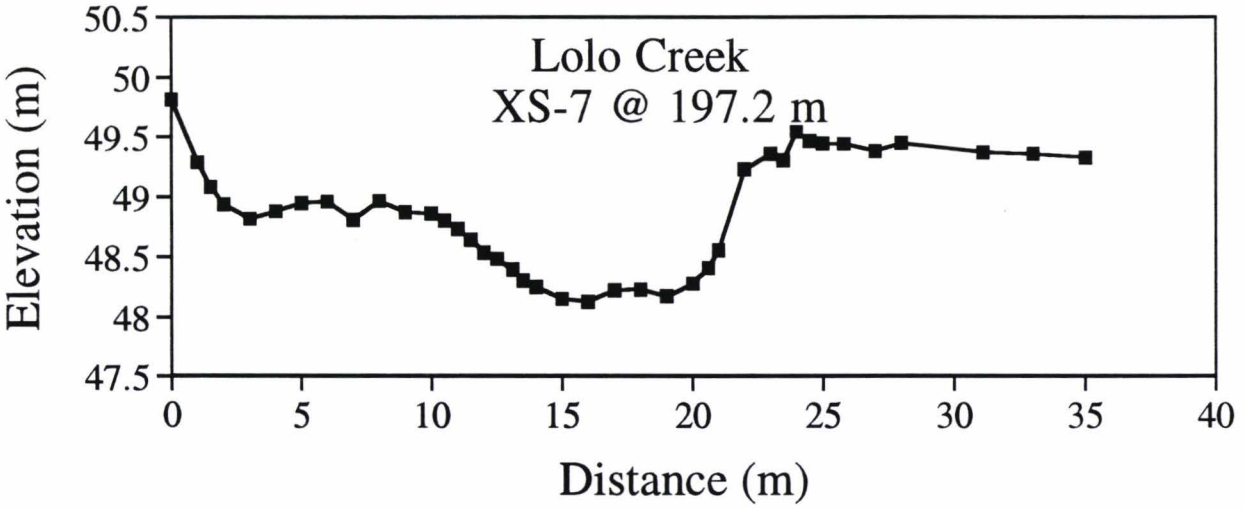

Little Slate Creek
XS-3 @ 94.7 m
Elevation (m)
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
Distance (m)

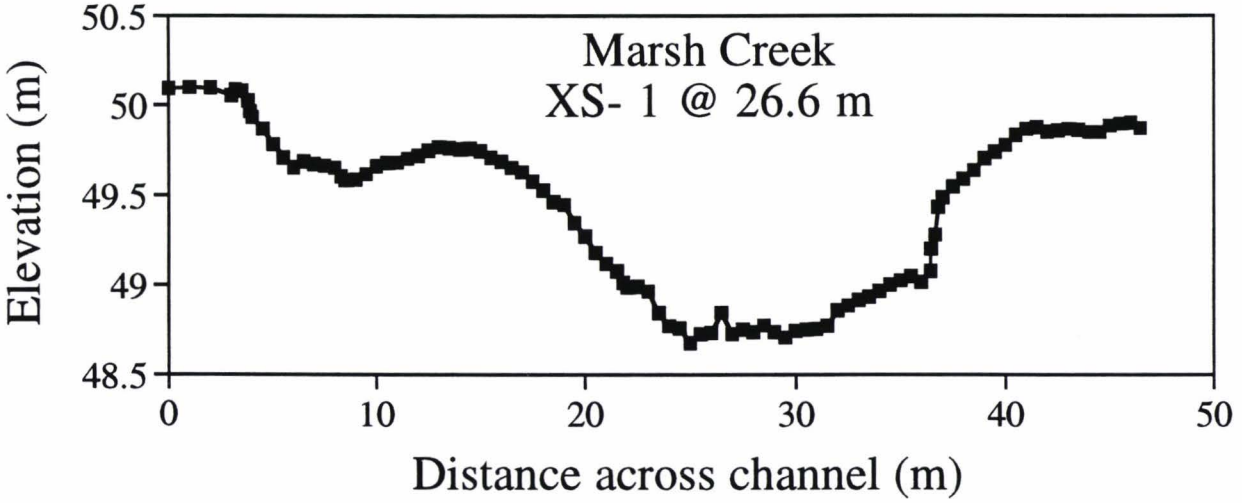

Little Slate Creek
XS-4 @ 190 m
Elevation (m)
53
52.5
52
51.5
51
50.5
0
5
10
15
20
25
Distance (m)

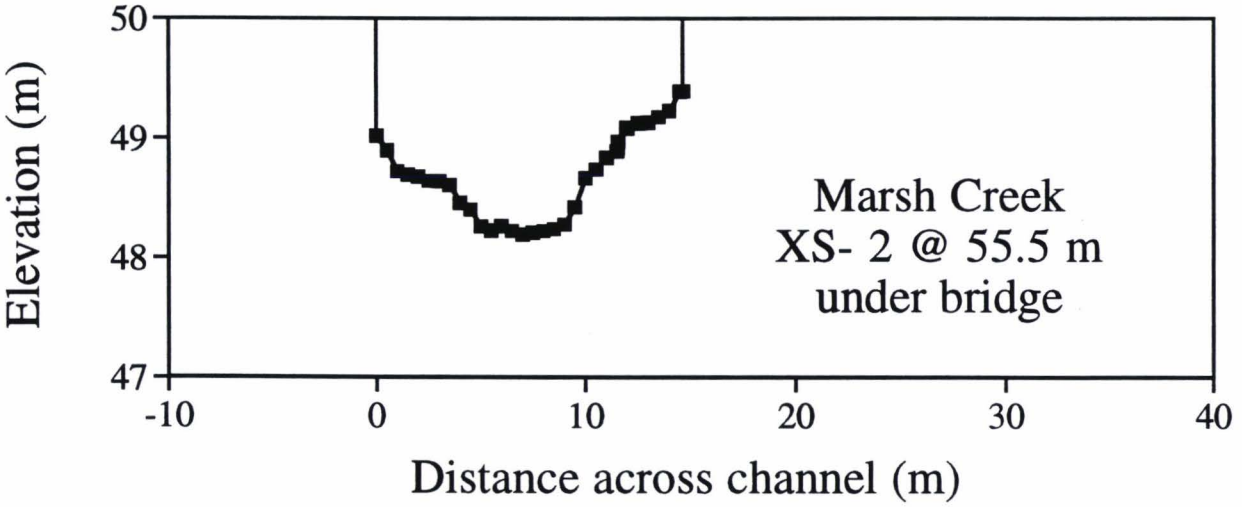

Lolo Creek
XS-2 @ 227.3 m
Elevation (m)
49.5
49
48.5
48
47.5
-5
0
5
10
15
20
25
30
Distance (m)

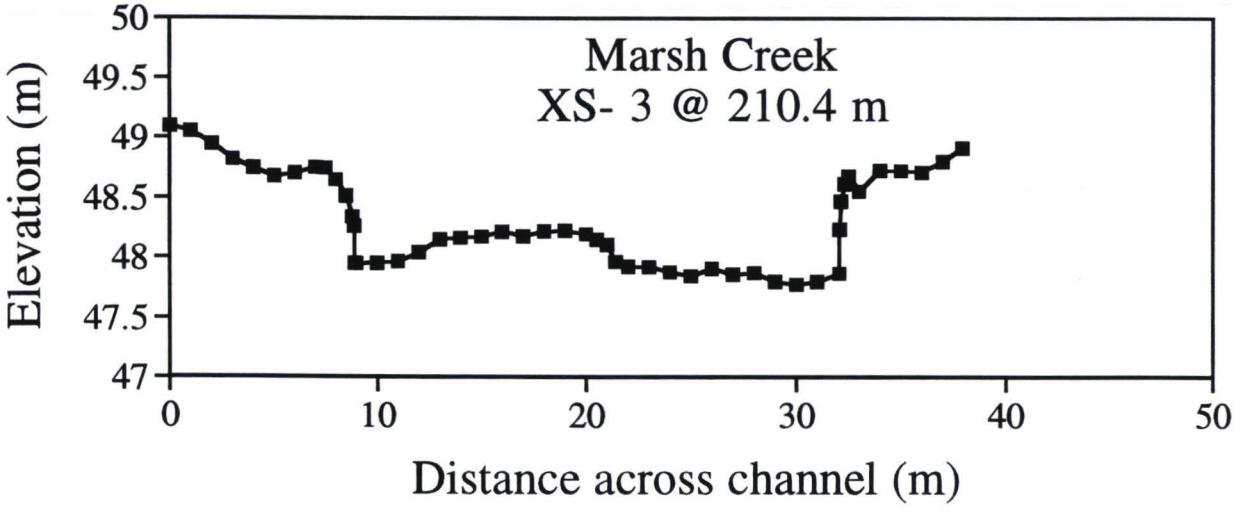

Lolo Creek
XS-5 @ 71.8 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
0
5
10
15
20
25
30
35
Distance (m)

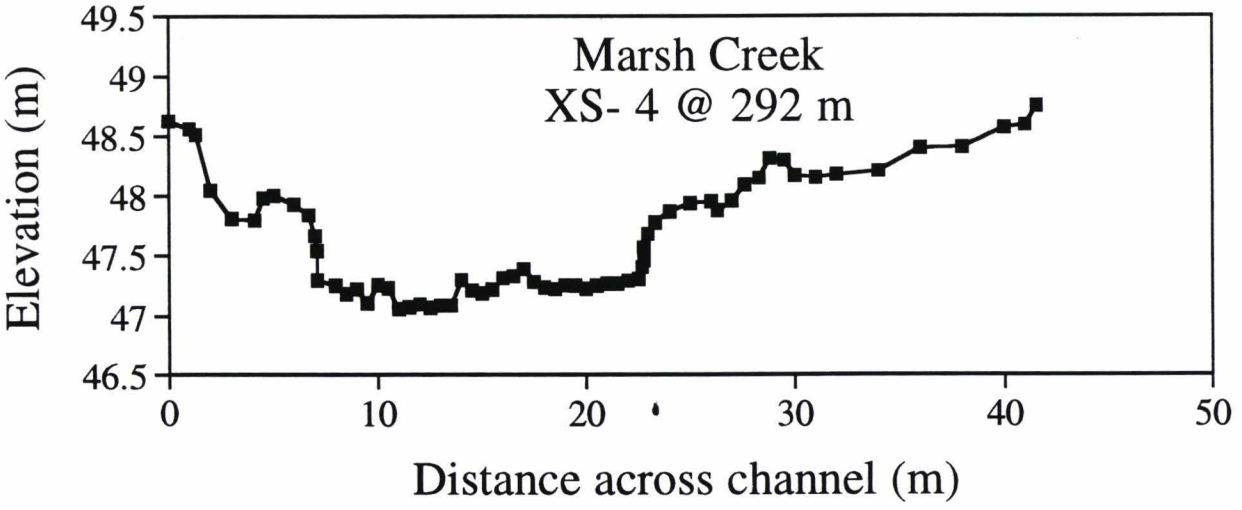

Lolo Creek
XS-6 @ 149.8 m
Elevation (m)
51.5
51
50.5
50
49.5
49
48.5
0
5
10
15
20
25
30
35
40
Distance (m)

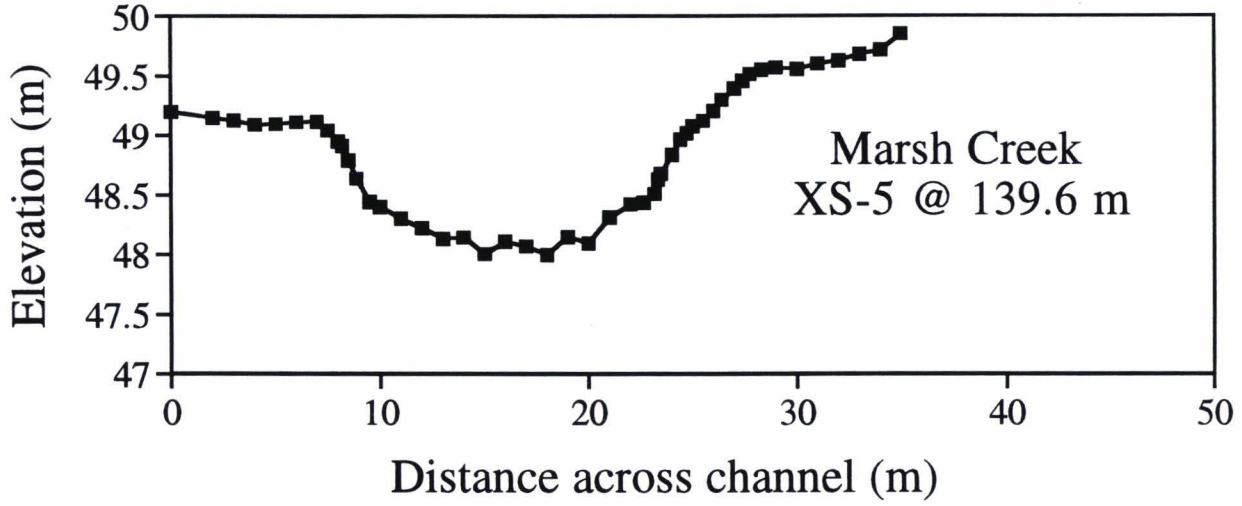

Lolo Creek
XS-7 @ 197.2 m
Elevation (m)
50.5
50
49.5
49
48.5
48
47.5
0
5
10
15
20
25
30
35
40
Distance (m)

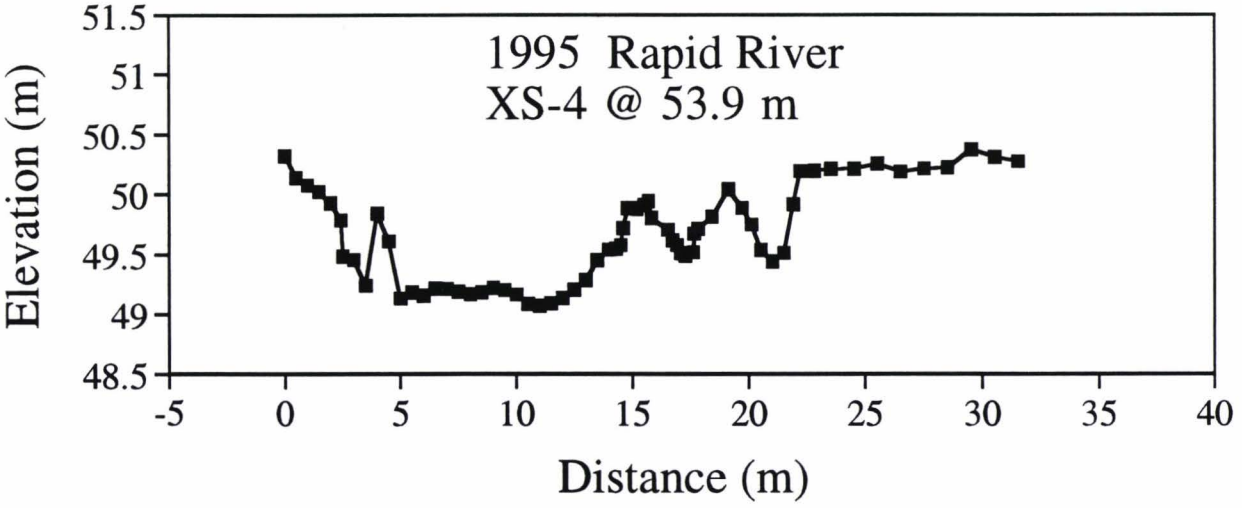

Marsh Creek
XS- 1 @ 26.6 m
Elevation (m)
50.5
50
49.5
49
48.5
0
10
20
30
40
50
Distance across channel (m)

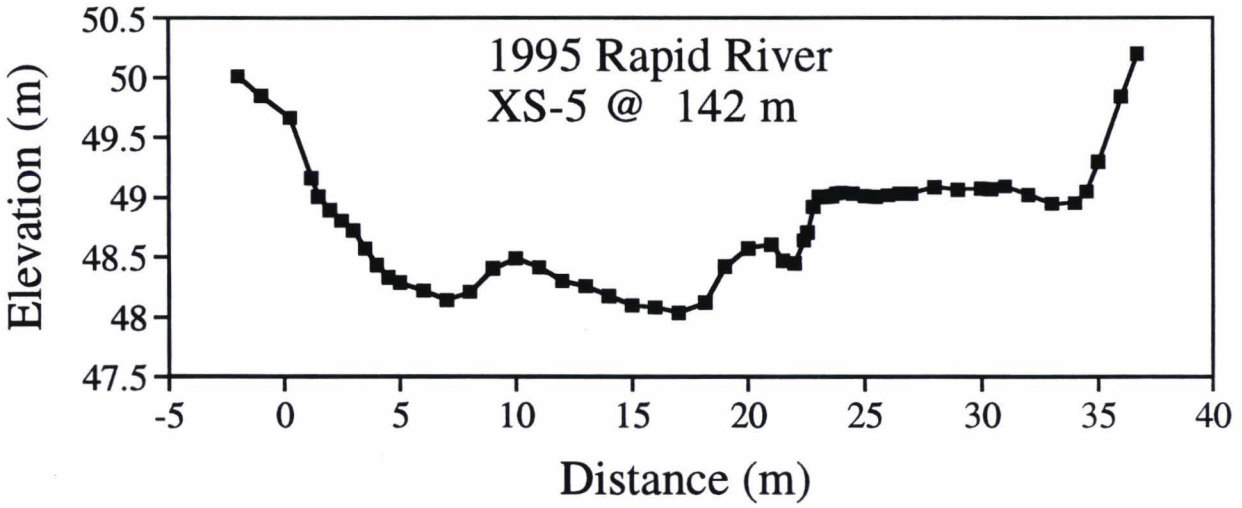

Marsh Creek
XS- 2 @ 55.5 m
under bridge
Elevation (m)
50
49
48
47
-10
0
10
20
30
40
Distance across channel (m)

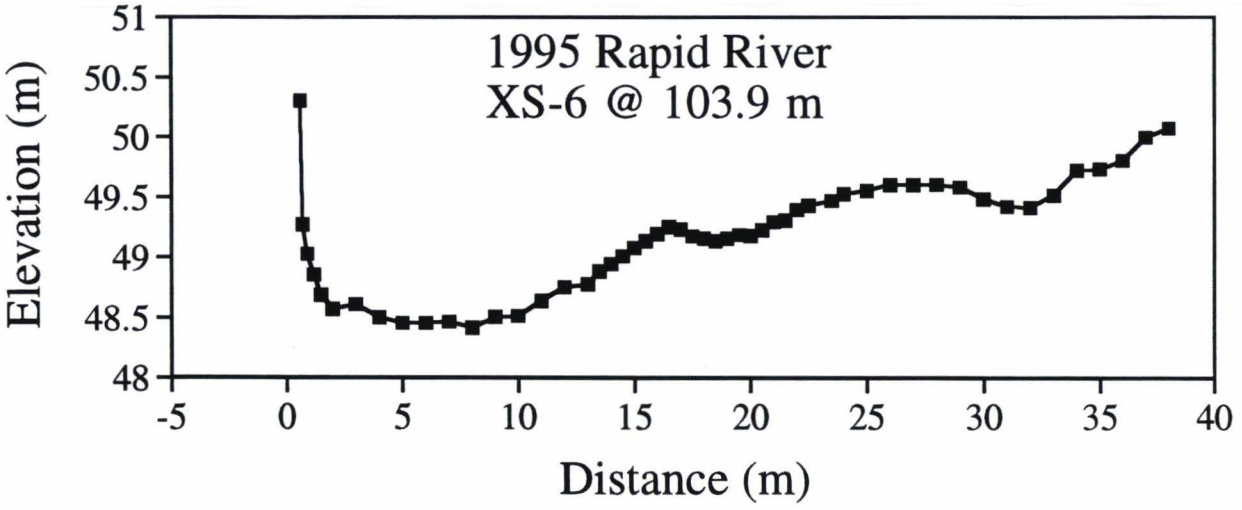

Marsh Creek
XS- 3 @ 210.4 m
Elevation (m)
50
49.5
49
48.5
48
47.5
47
0
10
20
30
40
50
Distance across channel (m)

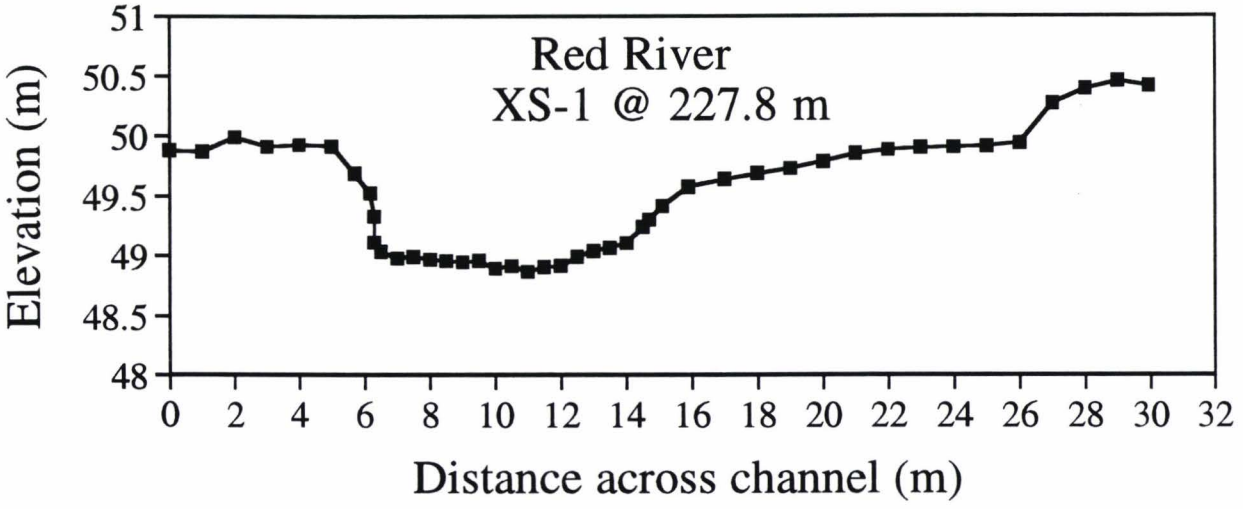

Marsh Creek
XS- 4 @ 292 m
Elevation (m)
49.5
49
48.5
48
47.5
47
46.5
0
10
20
30
40
50
Distance across channel (m)

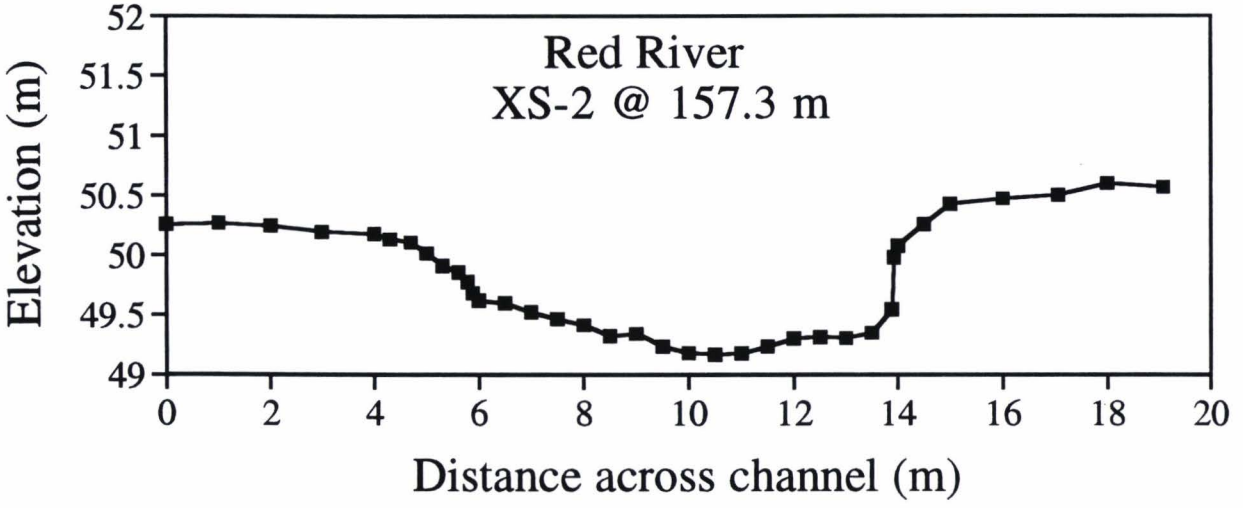

Marsh Creek
XS-5 @ 139.6 m
Elevation (m)
50
49.5
49
48.5
48
47.5
47
0
10
20
30
40
50
Distance across channel (m)

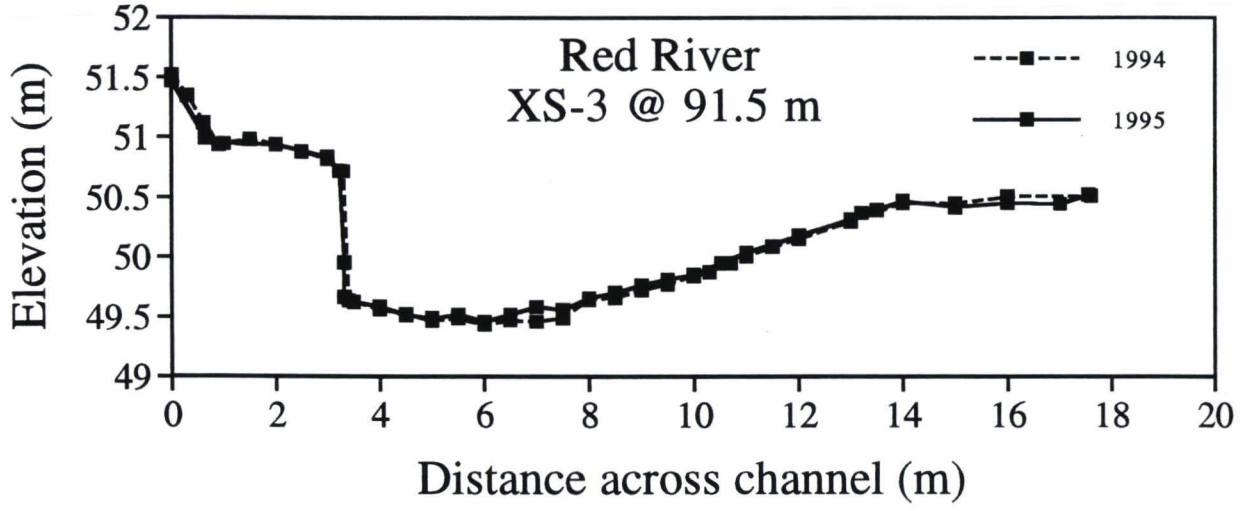

1995 Rapid River
XS-4 @ 53.9 m
Elevation (m)
51.5
51
50.5
50
49.5
49
48.5
-5
0
5
10
15
20
25
30
35
40
Distance (m)

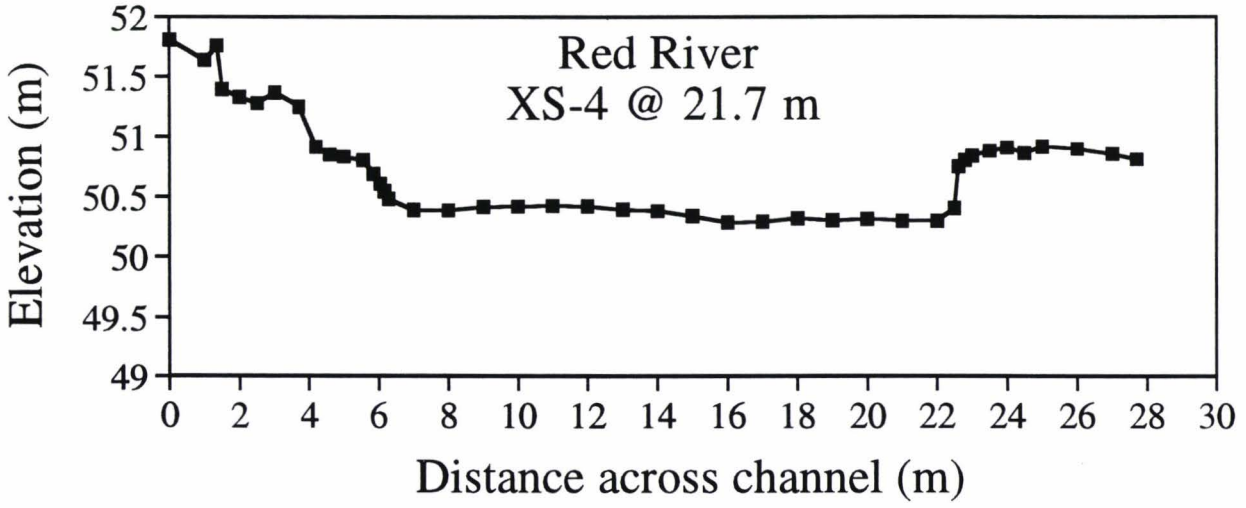

1995 Rapid River
XS-5 @ 142 m
Elevation (m)
50.5
50
49.5
49
48.5
48
47.5
-5
0
5
10
15
20
25
30
35
40
Distance (m)

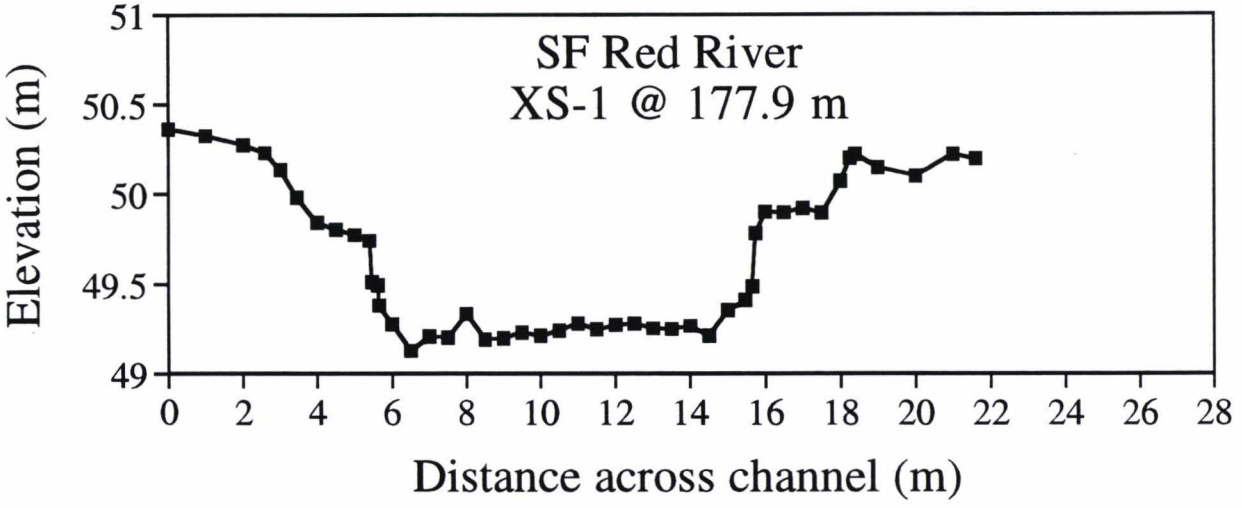

1995 Rapid River
XS-6 @ 103.9 m
Elevation (m)
51
50.5
50
49.5
49
48.5
48
-5
0
5
10
15
20
25
30
35
40
Distance (m)

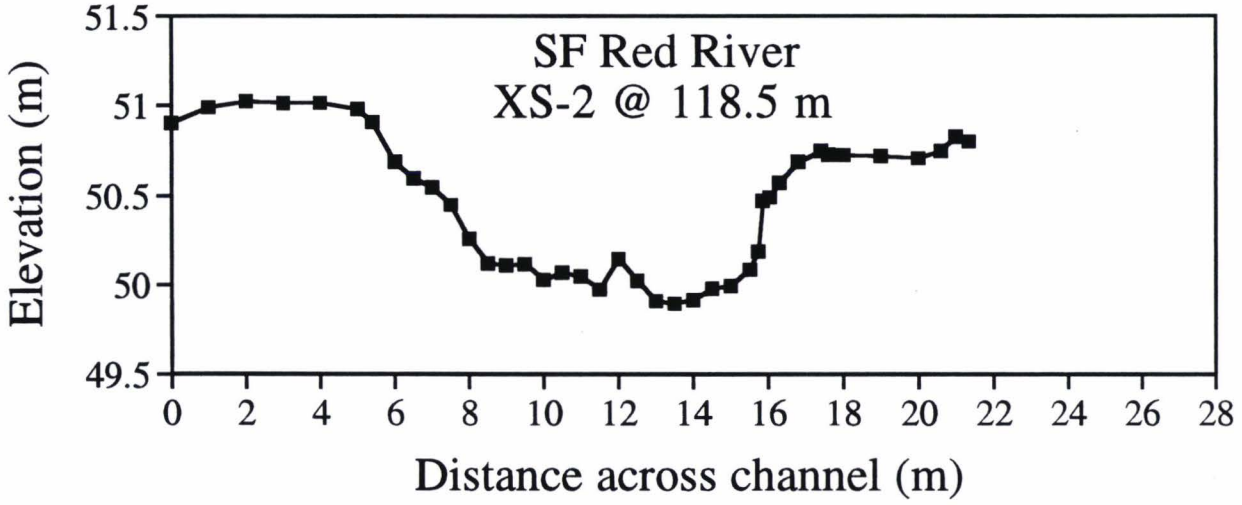

Red River
XS-1 @ 227.8 m
Elevation (m)
51
50.5
50
49.5
49
48.5
48
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
Distance across channel (m)

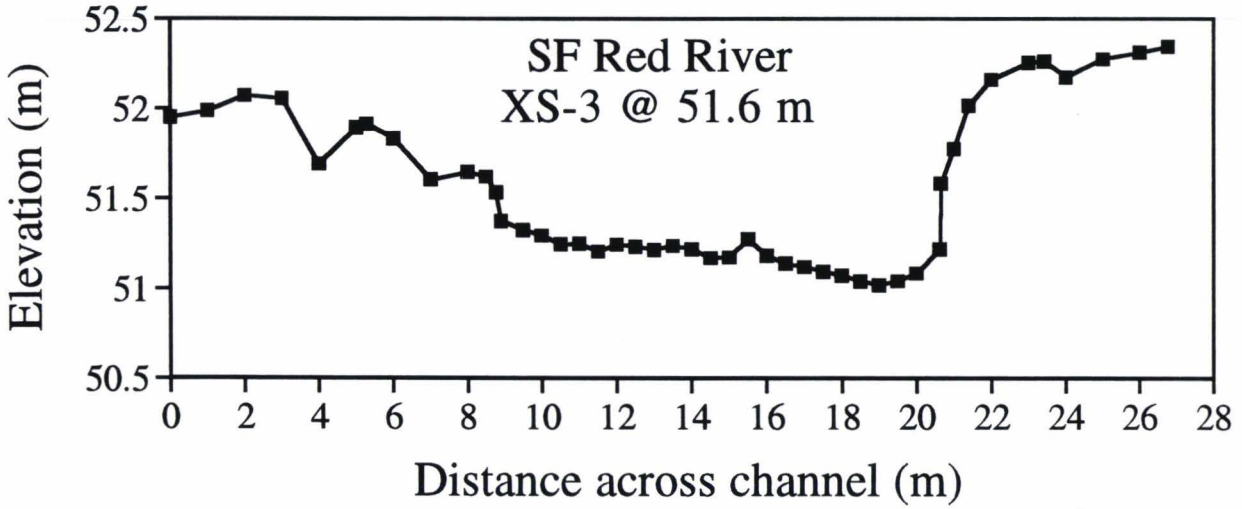

Red River
XS-2 @ 157.3 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
0 2 4 6 8 10 12 14 16 18 20
Distance across channel (m)

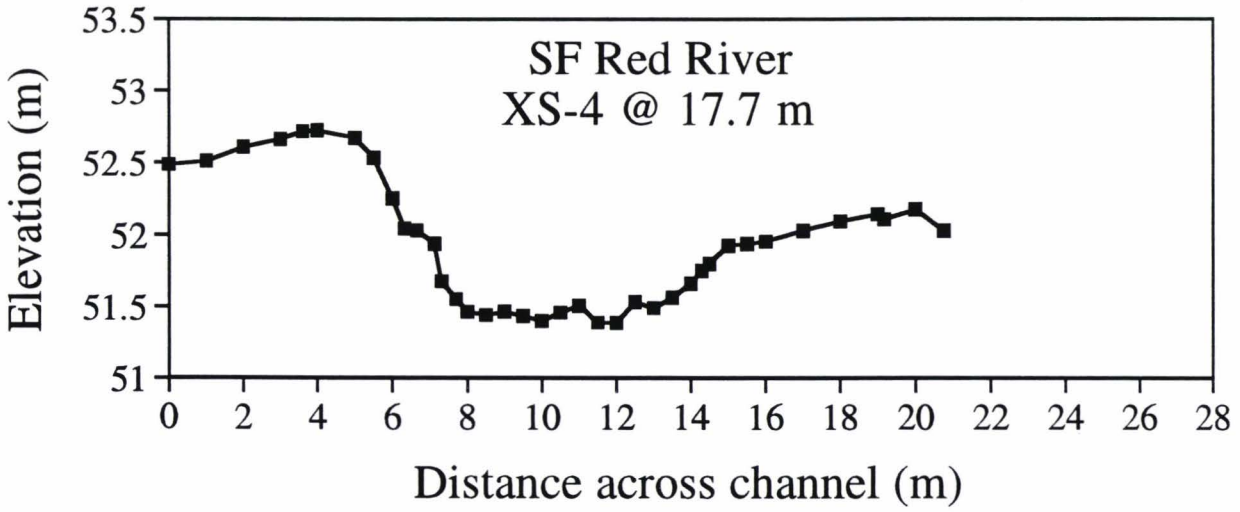

Red River
XS-3 @ 91.5 m
1994
1995
Elevation (m)
52
51.5
51
50.5
50
49.5
49
0 2 4 6 8 10 12 14 16 18 20
Distance across channel (m)

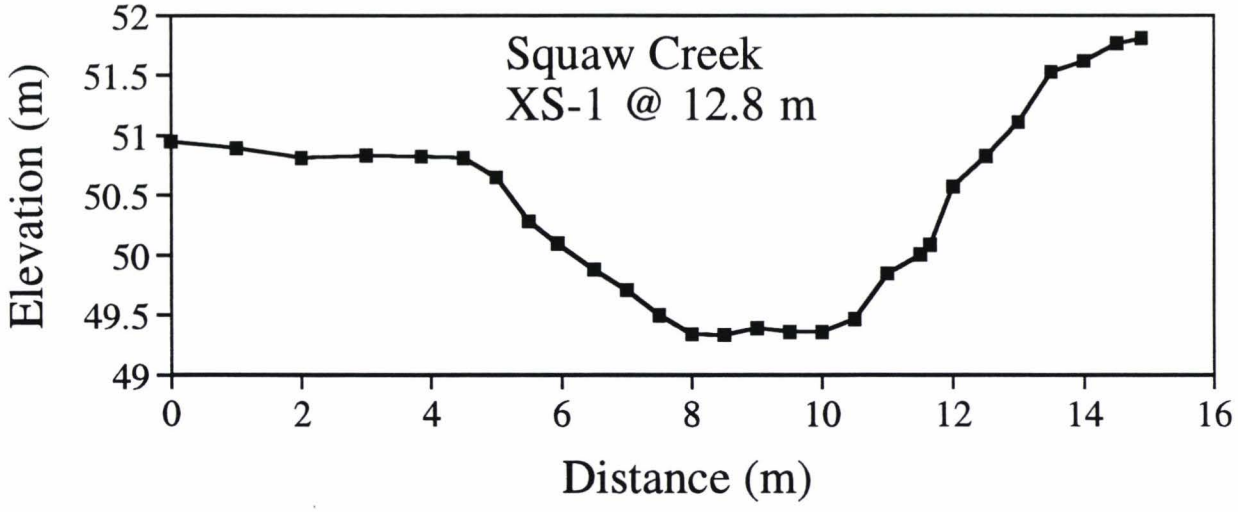

Red River
XS-4 @ 21.7 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Distance across channel (m)

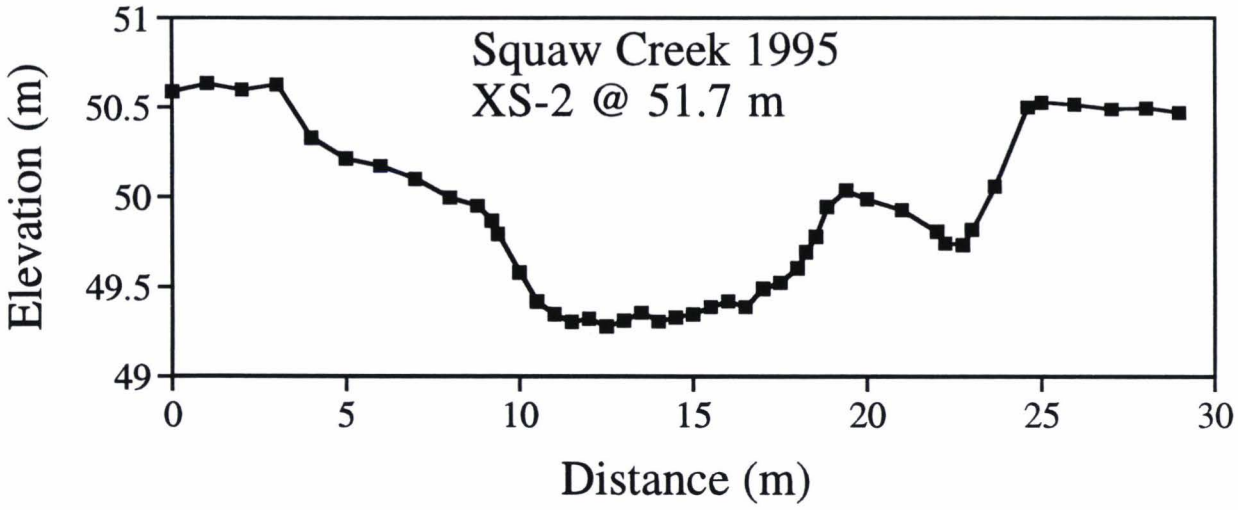

SF Red River
XS-1 @ 177.9 m
Elevation (m)
51
50.5
50
49.5
49
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Distance across channel (m)

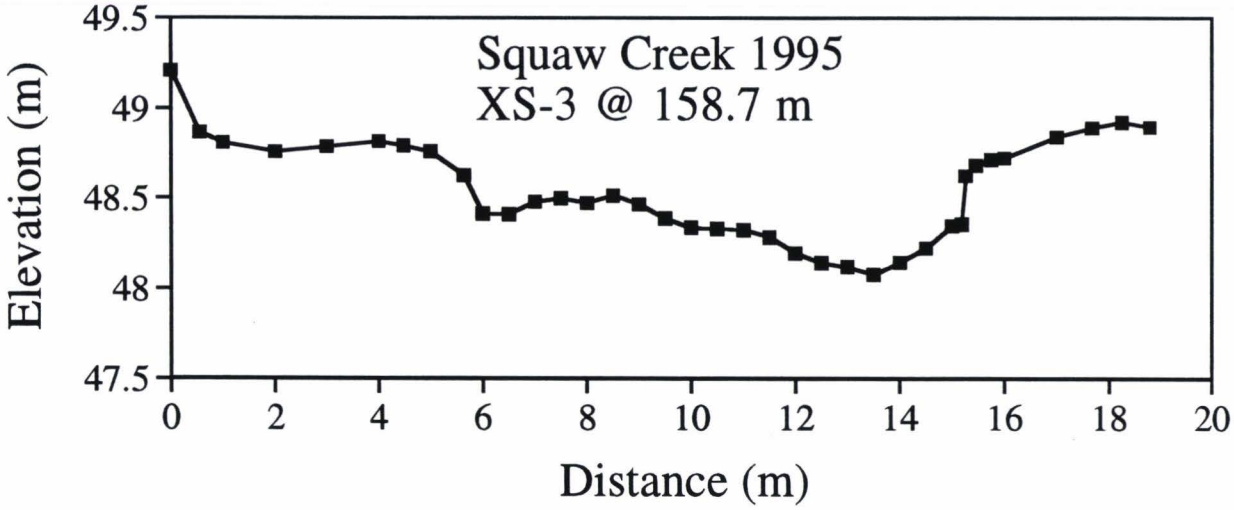

SF Red River
XS-2 @ 118.5 m
Elevation (m)
51.5
51
50.5
50
49.5
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Distance across channel (m)

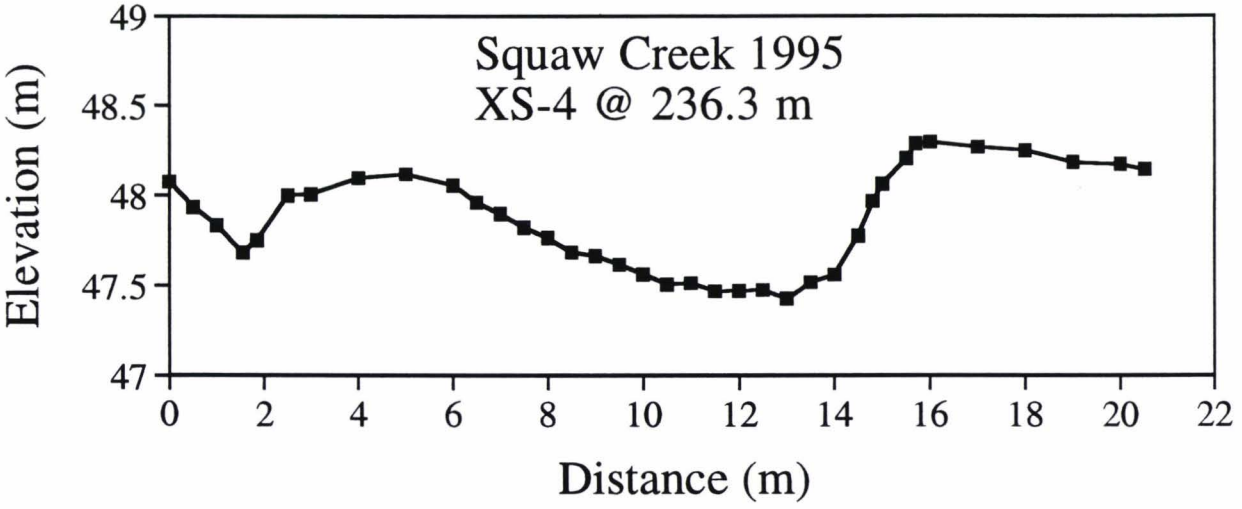

SF Red River
XS-3 @ 51.6 m
Elevation (m)
52.5
52
51.5
51
50.5
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Distance across channel (m)

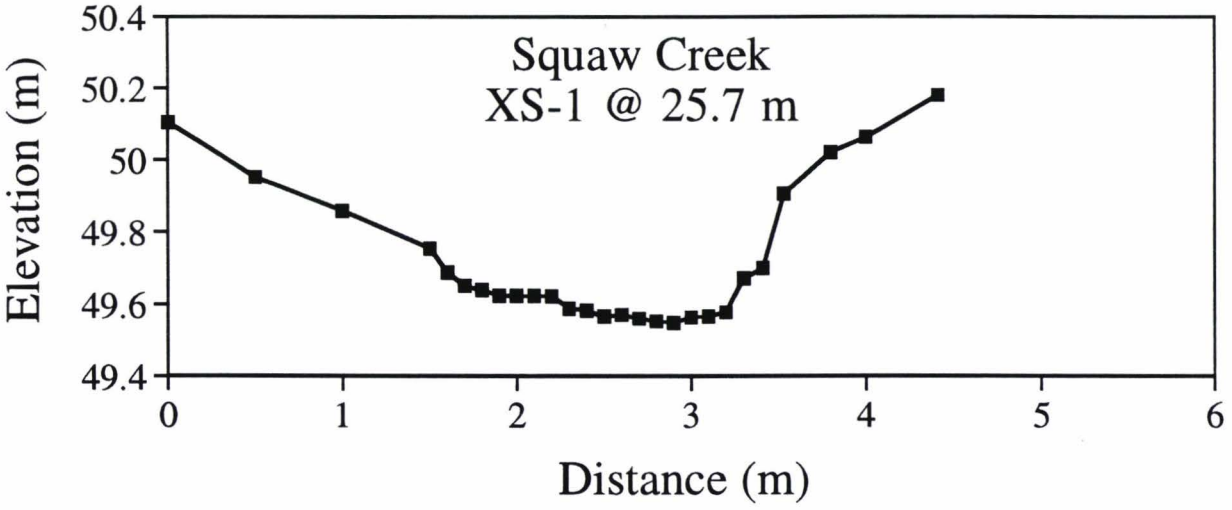

SF Red River
XS-4 @ 17.7 m
Elevation (m)
53.5
53
52.5
52
51.5
51
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Distance across channel (m)

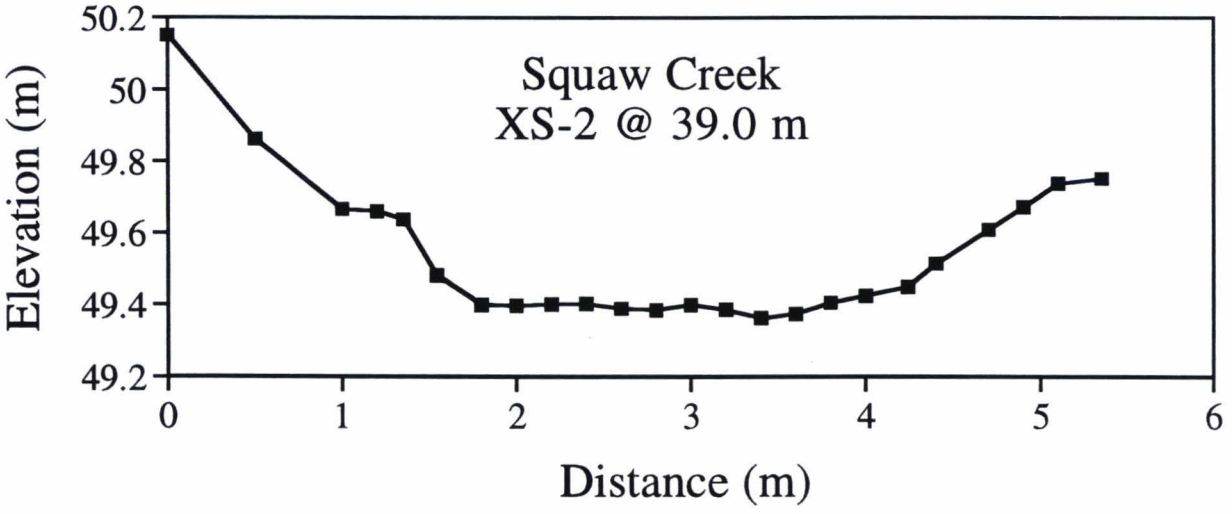

Squaw Creek
XS-1 @ 12.8 m
Elevation (m)
52
51.5
51
50.5
50
49.5
49
0
2
4
6
8
10
12
14
16
Distance (m)

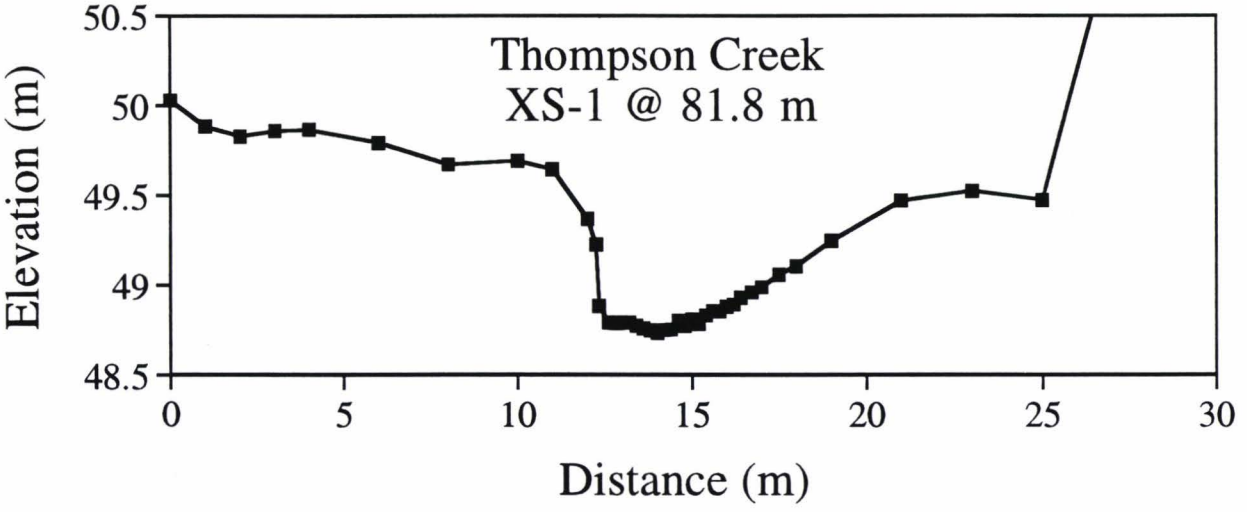

Squaw Creek 1995
XS-2 @ 51.7 m
Elevation (m)
51
50.5
50
49.5
49
0
5
10
15
20
25
30
Distance (m)

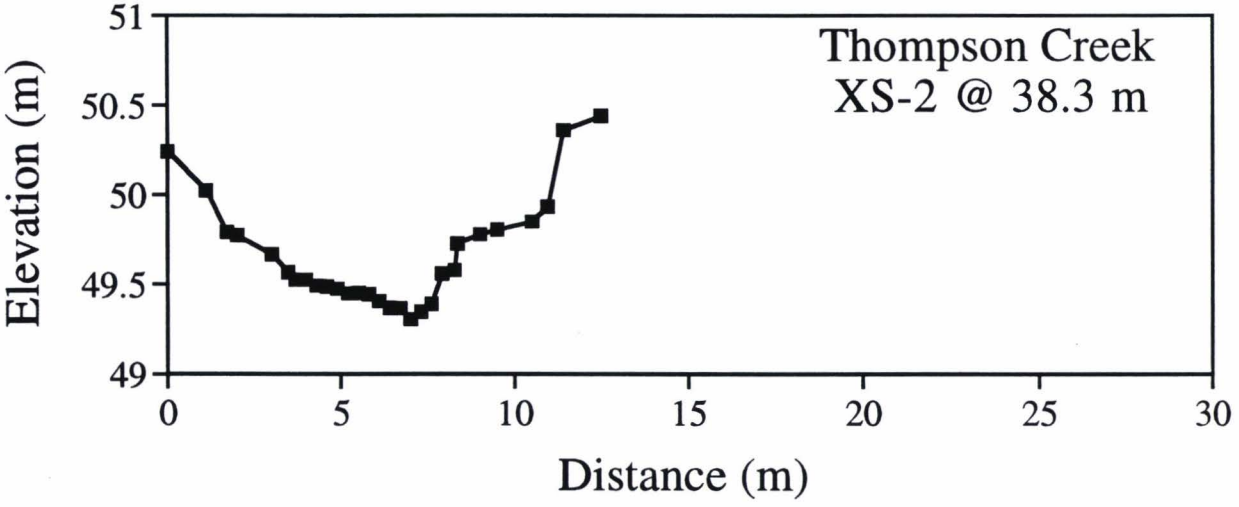

Squaw Creek 1995
XS-3 @ 158.7 m
Elevation (m)
49.5
49
48.5
48
47.5
0
2
4
6
8
10
12
14
16
18
20
Distance (m)

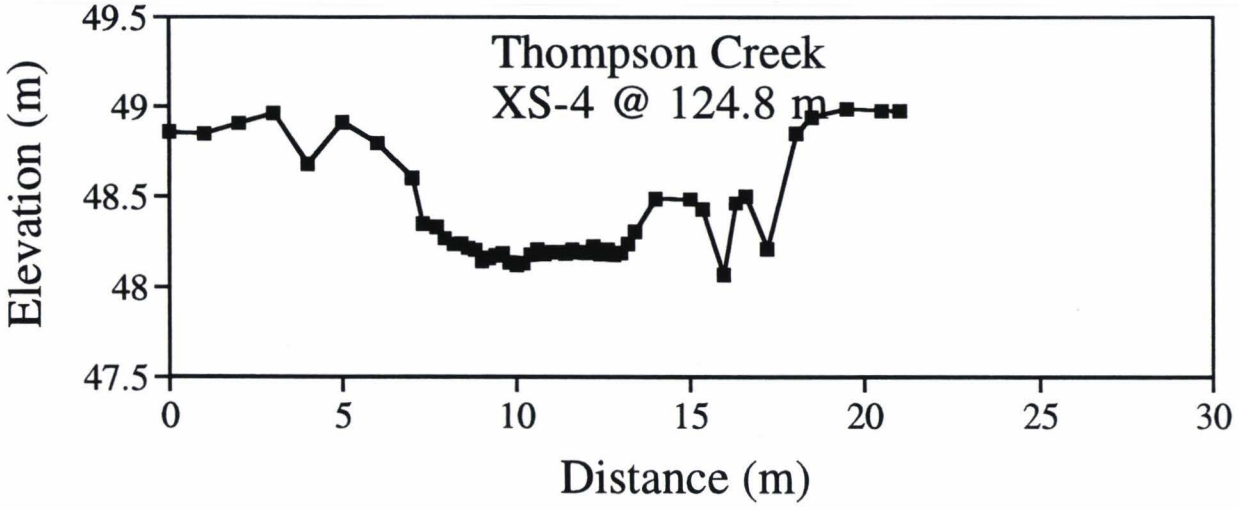

Squaw Creek 1995
XS-4 @ 236.3 m
Elevation (m)
49
48.5
48
47.5
47
0
2
4
6
8
10
12
14
16
18
20
22
Distance (m)

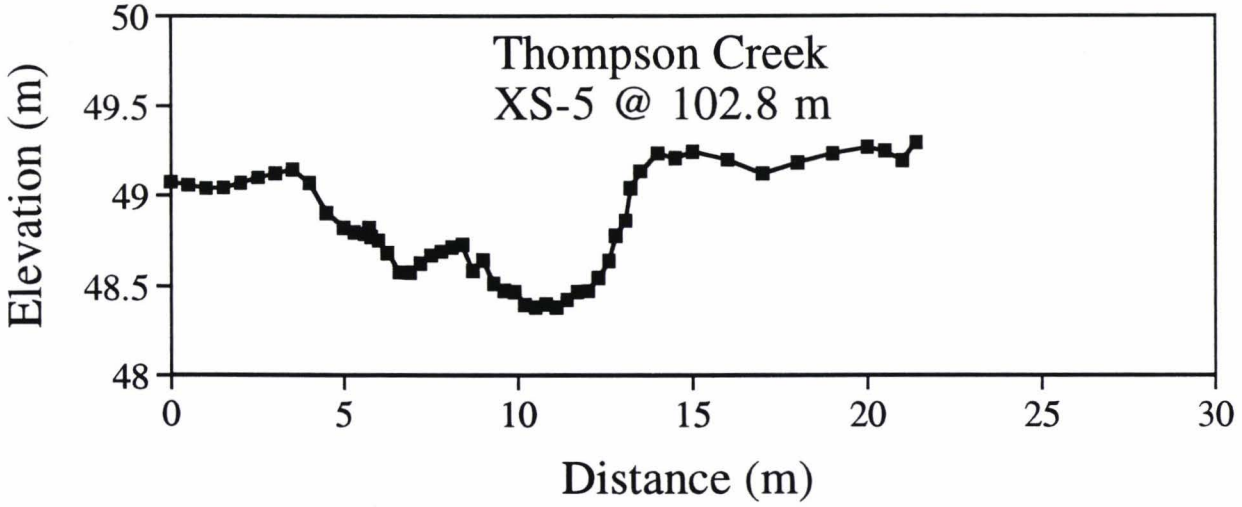

Squaw Creek
XS-1 @ 25.7 m
Elevation (m)
50.4
50.2
50
49.8
49.6
49.4
0
1
2
3
4
5
6
Distance (m)

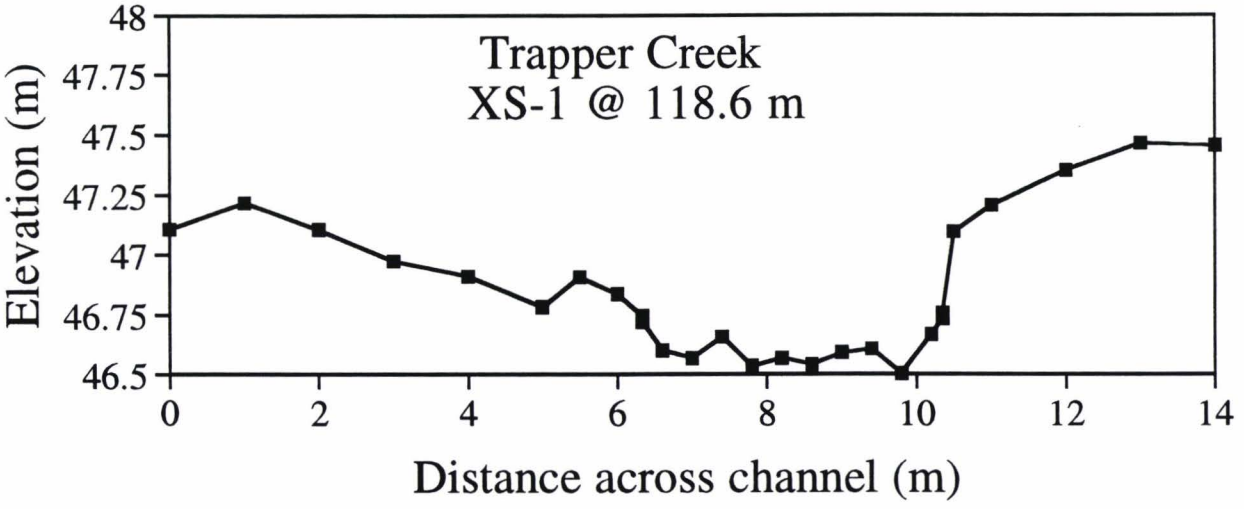

Squaw Creek
XS-2 @ 39.0 m
Elevation (m)
50.2
50
49.8
49.6
49.4
49.2
0
1
2
3
4
5
6
Distance (m)

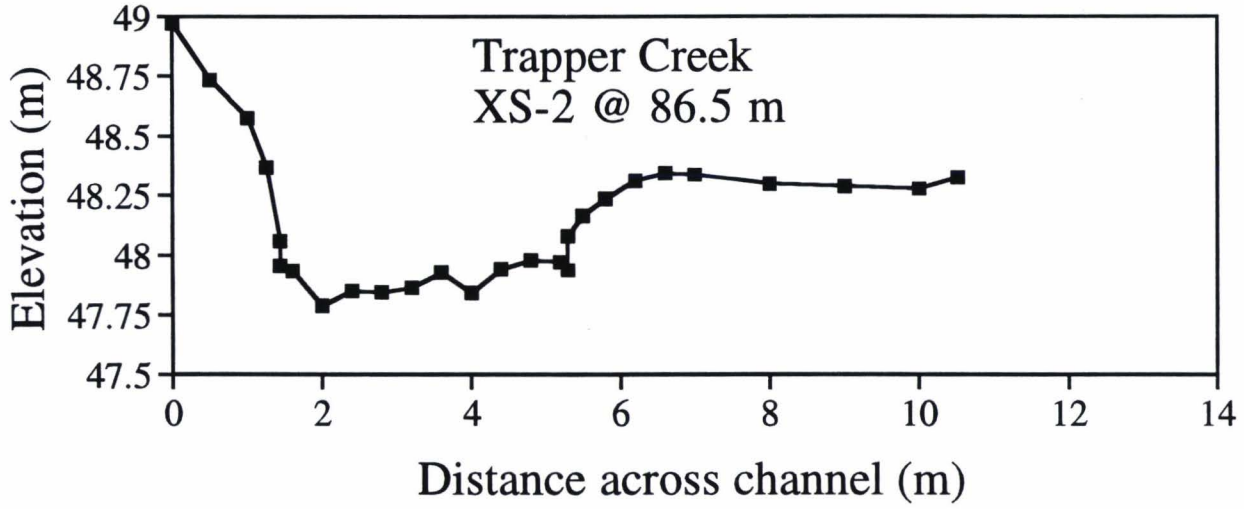

Thompson Creek
XS-1 @ 81.8 m
Elevation (m)
50.5
50
49.5
49
48.5
0
5
10
15
20
25
30
Distance (m)

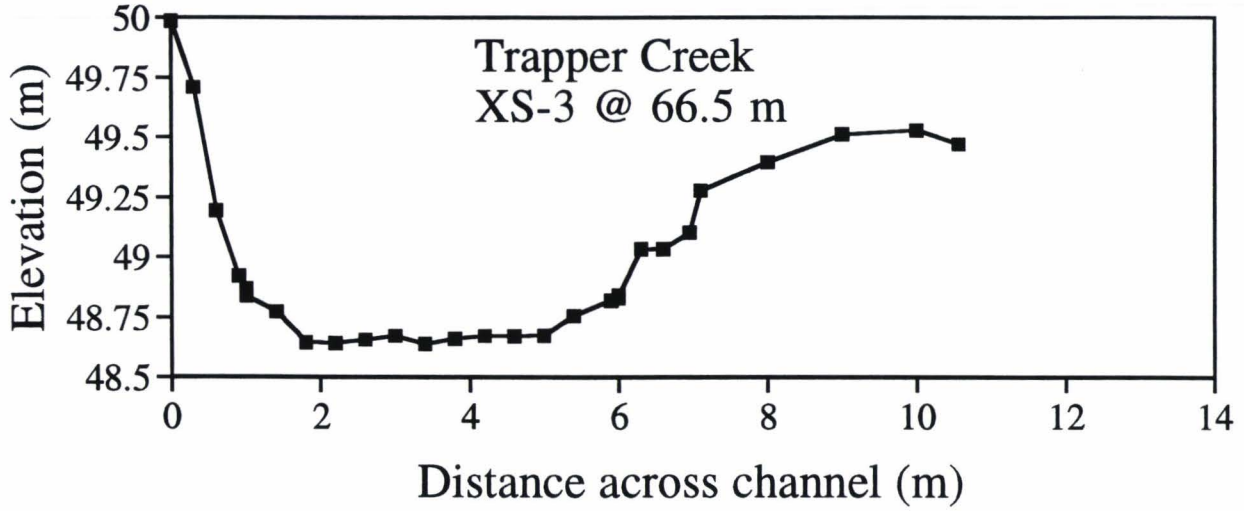

Thompson Creek
XS-2 @ 38.3 m
Elevation (m)
51
50.5
50
49.5
49
0
5
10
15
20
25
30
Distance (m)

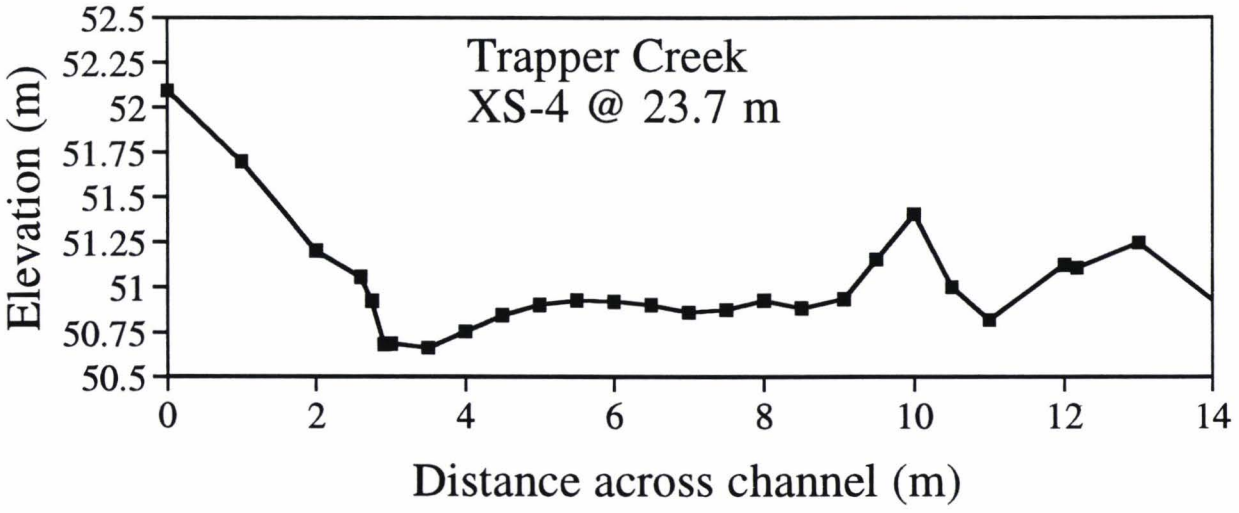

Thompson Creek
XS-4 @ 124.8 m
Elevation (m)
49.5
49
48.5
48
47.5
0
5
10
15
20
25
30
Distance (m)

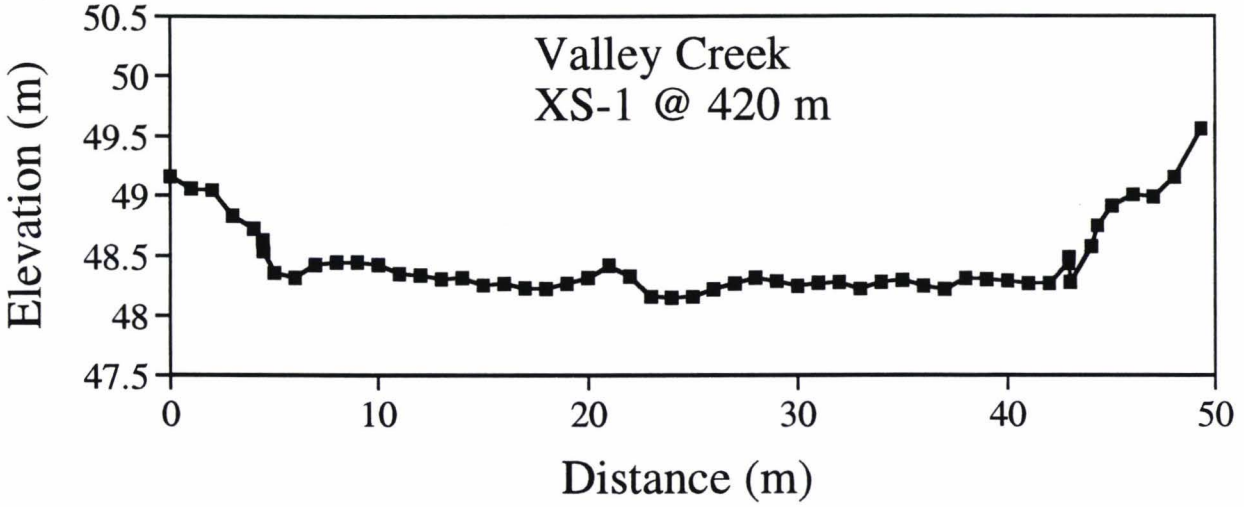

Thompson Creek
XS-5 @ 102.8 m
Elevation (m)
50
49.5
49
48.5
48
0
5
10
15
20
25
30
Distance (m)

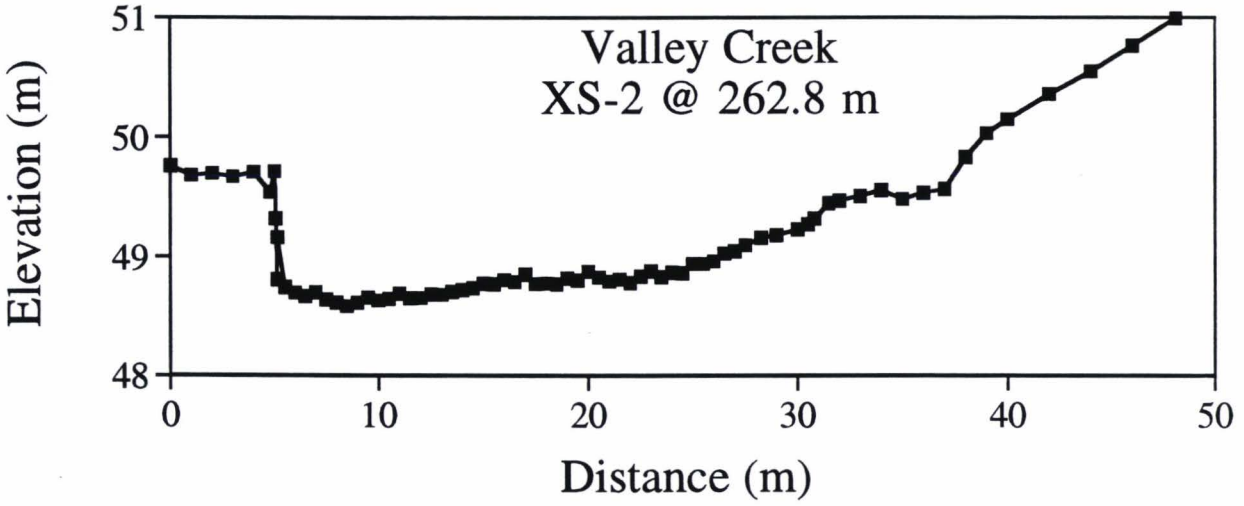

Trapper Creek
XS-1 @ 118.6 m
Elevation (m)
48
47.75
47.5
47.25
47
46.75
46.5
0
2
4
6
8
10
12
14
Distance across channel (m)

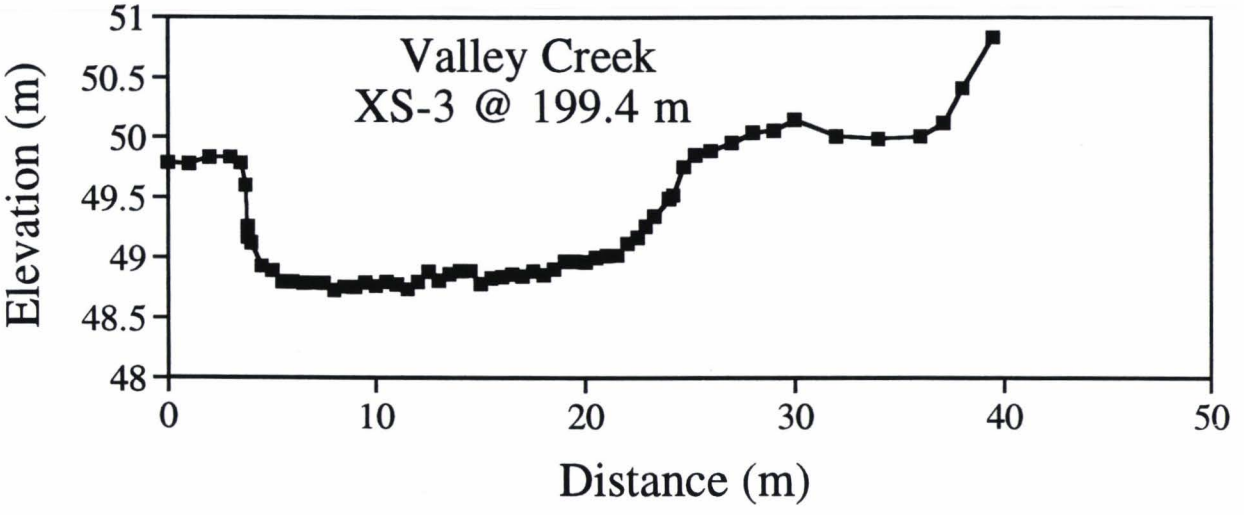

Trapper Creek
XS-2 @ 86.5 m
Elevation (m)
49
48.75
48.5
48.25
48
47.75
47.5
0
2
4
6
8
10
12
14
Distance across channel (m)

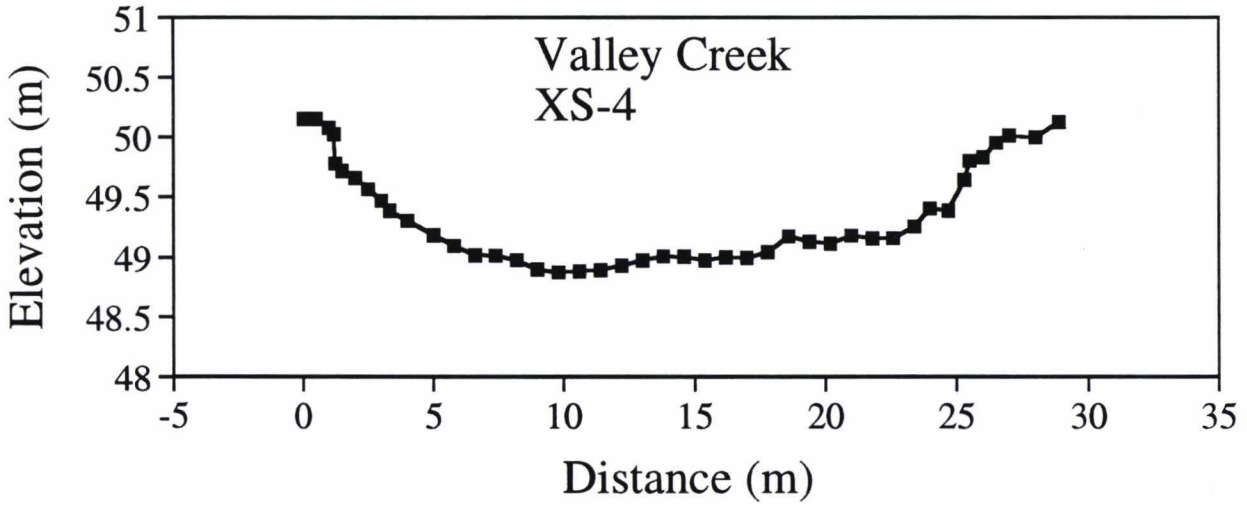

Trapper Creek
XS-3 @ 66.5 m
Elevation (m)
50
49.75
49.5
49.25
49
48.75
48.5
0
2
4
6
8
10
12
14
Distance across channel (m)

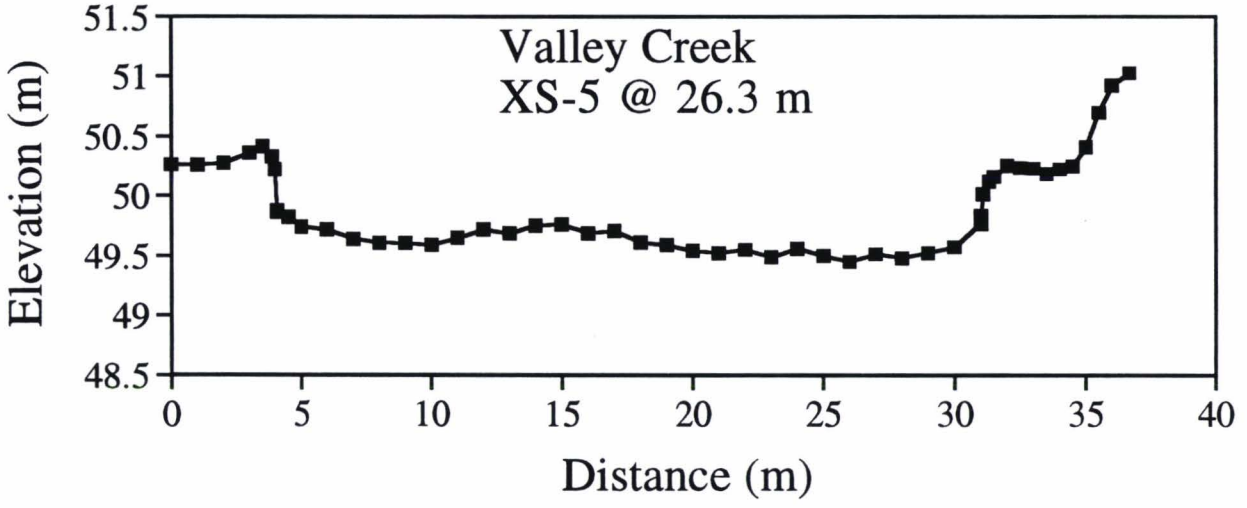

Trapper Creek
XS-4 @ 23.7 m
Elevation (m)
52.5
52.25
52
51.75
51.5
51.25
51
50.75
50.5
0
2
4
6
8
10
12
14
Distance across channel (m)

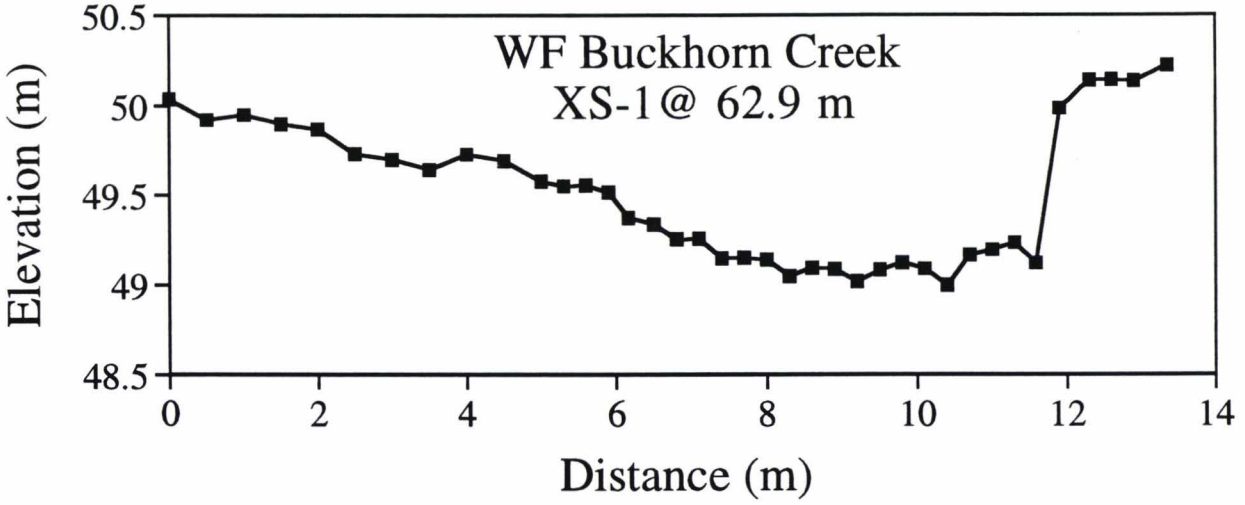

Valley Creek
XS-1 @ 420 m
Elevation (m)
50.5
50
49.5
49
48.5
48
47.5
0
10
20
30
40
50
Distance (m)

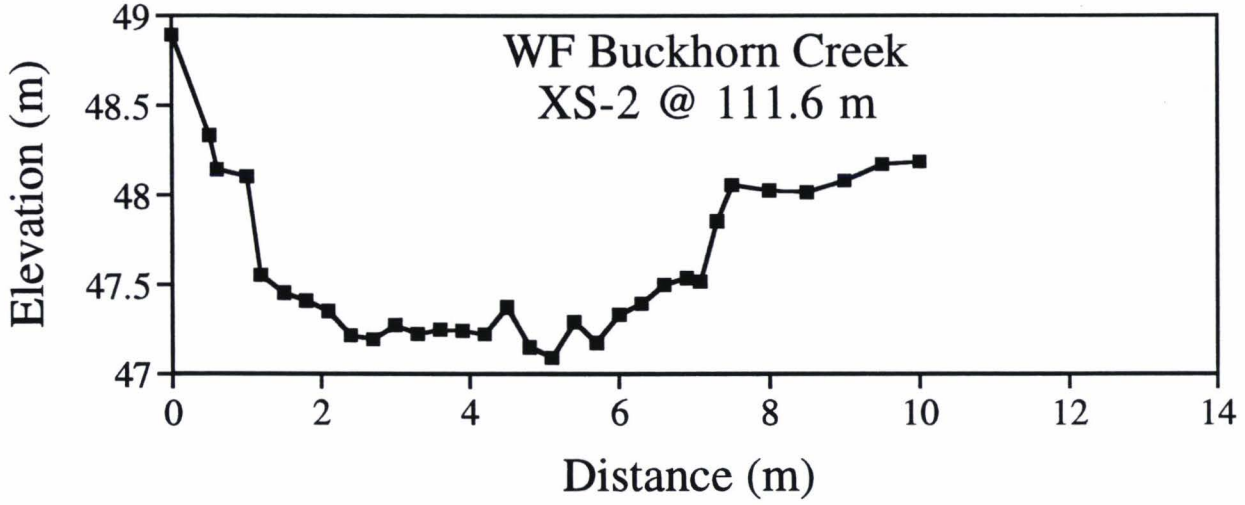

Valley Creek
XS-2 @ 262.8 m
Elevation (m)
51
50
49
48
0
10
20
30
40
50
Distance (m)

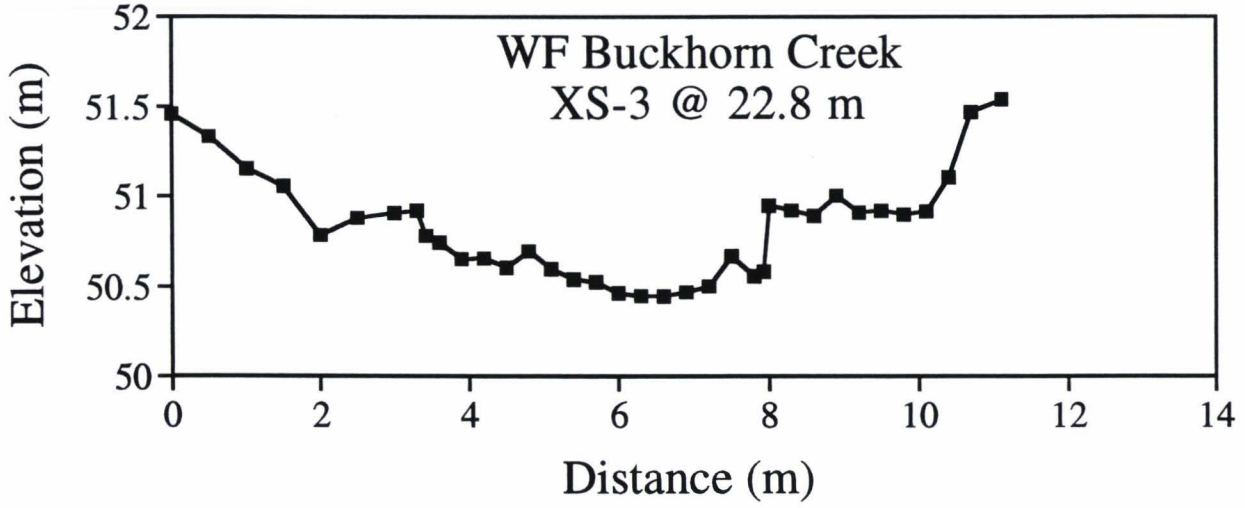

Valley Creek
XS-3 @ 199.4 m
Elevation (m)
51
50.5
50
49.5
49
48.5
48
0
10
20
30
40
50
Distance (m)


Valley Creek
XS-4
Elevation (m)
Distance (m)
51
50.5
50
49.5
49
48.5
48
-5
0
5
10
15
20
25
30
35

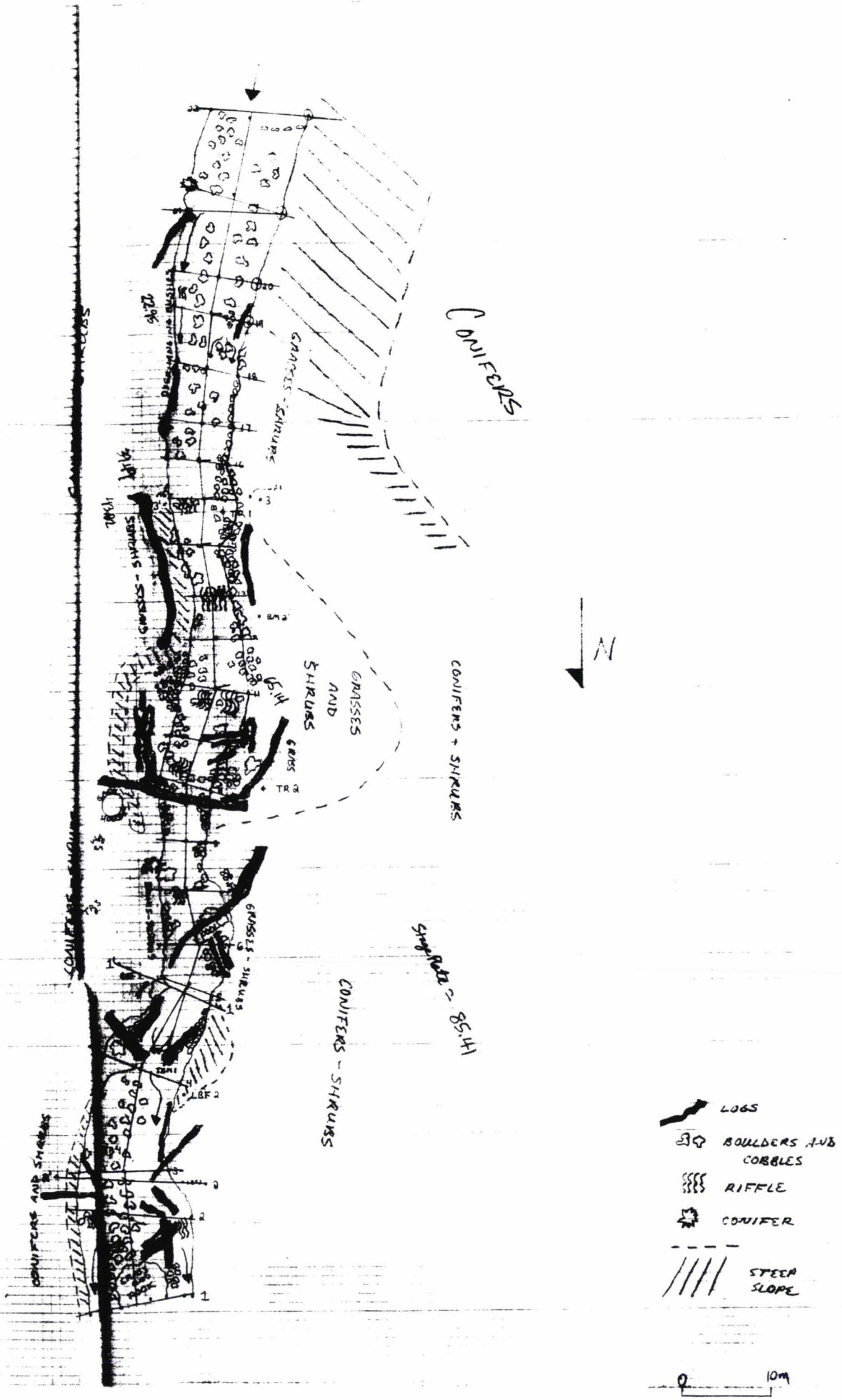

Valley Creek
XS-5 @ 26.3 m
Elevation (m)
Distance (m)
51.5
51
50.5
50
49.5
49
48.5
0
5
10
15
20
25
30
35
40


WF Buckhorn Creek
XS-1@ 62.9 m
Elevation (m)
50.5
50
49.5
49
48.5
0
2
4
6
8
10
12
14
Distance (m)


WF Buckhorn Creek
XS-2 @ 111.6 m
Elevation (m)
49
48.5
48
47.5
47
0
2
4
6
8
10
12
14
Distance (m)


WF Buckhorn Creek
XS-3 @ 22.8 m
Elevation (m)
52
51.5
51
50.5
50
0
2
4
6
8
10
12
14
Distance (m)

BLACKMARE CR



Pebble counts

Blackmare Cr	% finer	Canyon Cr	% finer	Catspur Cr	% finer	Dollar Creek	% finer	Eggers Cr	% finer	Fish Cr	% finer	4 July Creek	% finer	Hawley Cr	% finer
(mm)		(mm)		(mm)		(mm)		(mm)		(mm)		(mm)		(mm)	
365	100	1000	100	180	100	401	100.00	89	100	99999	100	600	100	340	100
323	99	1000	99	170	99	378	98.91	70	99	99999	99	600	99.02	340	99
300	98	1000	98	134	98	378	97.83	25	98	99999	98	250	98.04	340	98
296	97	1000	97	110	97	308	96.74	20	97	99999	97	250	97.06	340	97
290	96	660	96	105	96	211	95.65	20	96	99999	96	240	96.08	340	96
278	95	660	95	102	95	188	94.57	12	95	99999	95	182	95.10	260	95
267	94	660	94	100	94	184	93.48	10	94	99999	94	174	94.12	260	94
260	93	650	93	100	93	182	92.39	10	93	99999	93	170	93.14	260	93
254	92	650	92	90	92	175	91.30	9	92	99999	92	150	92.16	160	92
254	91	550	91	85	91	171	90.22	9	91	99999	91	142	91.18	150	91
252	90	550	90	80	90	164	89.13	8	90	99999	90	139	90.20	140	90
250	89	500	89	80	89	155	88.04	8	89	99999	89	129	89.22	120	89
248	88	500	88	80	88	150	86.96	8	88	99999	88	120	88.24	110	88
245	87	460	87	75	87	150	85.87	8	87	99999	87	120	87.25	110	87
230	86	460	86	75	86	146	84.78	7	86	99999	86	115	86.27	100	86
222	85	450	85	75	85	145	83.70	7	85	99999	85	112	85.29	100	85
220	84	450	84	73	84	144	82.61	7	84	99999	84	110	84.31	100	84
214	83	450	83	70	83	132	81.52	7	83	99999	83	110	83.33	99	83
214	82	420	82	68	82	130	80.43	7	82	99999	82	105	82.35	95	82
208	81	400	81	67	81	130	79.35	6	81	99999	81	100	81.37	91	81
200	80	400	80	65	80	116	78.26	6	80	99999	80	100	80.39	90	80
200	79	400	79	62	79	113	77.17	6	79	99999	79	99	79.41	86	79
190	78	380	78	57	78	113	76.09	6	78	99999	78	98	78.43	85	78
185	77	380	77	56	77	107	75.00	5	77	99999	77	98	77.45	85	77
184	76	350	76	55	76	104	73.91	5	76	99999	76	93	76.47	82	76
180	75	350	75	55	75	103	72.83	5	75	99999	75	93	75.49	80	75
180	74	310	74	50	74	98	71.74	5	74	99999	74	91	74.51	78	74
175	73	310	73	50	73	97	70.65	5	73	99999	73	89	73.53	75	73
175	72	300	72	45	72	97	69.57	5	72	99999	72	88	72.55	72	72
170	71	300	71	40	71	94	68.48	5	71	99999	71	87	71.57	71	71
167	70	300	70	40	70	94	67.39	5	70	99999	70	84	70.59	70	70
166	69	250	69	37	69	92	66.30	5	69	700	69	80	69.61	70	69
163	68	240	68	34	68	91	65.22	5	68	700	68	78	68.63	70	68
163	67	230	67	33	67	91	64.13	5	67	650	67	73	67.65	68	67
150	66	210	66	33	66	91	63.04	5	66	650	66	70	66.67	66	66
146	65	190	65	33	65	90	61.96	5	65	600	65	69	65.69	60	65
146	64	190	64	32	64	90	60.87	5	64	550	64	67	64.71	60	64
140	63	190	63	32	63	89	59.78	5	63	500	63	66	63.73	58	63
139	62	180	62	31	62	86	58.70	5	62	470	62	65	62.75	52	62
133	61	180	61	30	61	81	57.61	5	61	470	61	61	61.76	52	61
132	60	170	60	30	60	81	56.52	5	60	450	60	59	60.78	50	60
128	59	160	59	30	59	79	55.43	5	59	410	59	58	59.80	48	59
126	58	160	58	30	58	78	54.35	5	58	400	58	57	58.82	47	58
114	57	150	57	30	57	78	53.26	4	57	370	57	56	57.84	47	57
106	56	150	56	30	56	78	52.17	4	56	360	56	56	56.86	46	56
103	55	150	55	30	55	77	51.09	4	55	350	55	55	55.88	46	55
100	54	150	54	28	54	74	50.00	4	54	350	54	54	54.90	44	54
99	53	150	53	28	53	73	48.91	4	53	340	53	53	53.92	42	53
98	52	140	52	27	52	72	47.83	4	52	330	52	52	52.94	41	52
97	51	140	51	27	51	72	46.74	4	51	330	51	52	51.96	40	51
95	50	140	50	27	50	70	45.65	4	50	330	50	52	50.98	40	50
94	49	140	49	26	49	70	44.57	4	49	330	49	51	50.00	36	49
93	48	140	48	26	48	68	43.48	4	48	320	48	50	49.02	36	48
90	47	140	47	26	47	65	42.39	4	47	320	47	50	48.04	35	47
90	46	135	46	25	46	60	41.30	3	46	320	46	50	47.06	35	46
85	45	132	45	25	45	58	40.22	3	45	310	45	48	46.08	33	45
85	44	130	44	25	44	58	39.13	3	44	300	44	48	45.10	33	44
84	43	130	43	25	43	57	38.04	3	43	260	43	47	44.12	32	43
83	42	130	42	25	42	54	36.96	3	42	260	42	44	43.14	31	42
83	41	120	41	24	41	52	35.87	3	41	250	41	44	42.16	31	41
83	40	111	40	24	40	50	34.78	3	40	250	40	41	41.18	31	40
82	39	111	39	23	39	49	33.70	3	39	230	39	40	40.20	30	39
80	38	110	38	23	38	48	32.61	3	38	200	38	40	39.22	30	38
80	37	110	37	23	37	47	31.52	3	37	170	37	40	38.24	29	37
80	36	110	36	22	36	41	30.43	3	36	170	36	40	37.25	28	36
79	35	110	35	22	35	40	29.35	3	35	140	35	37	36.27	27	35
79	34	100	34	22	34	36	28.26	3	34	140	34	37	35.29	26	34
75	33	95	33	22	33	35.7	27.17	3	33	132	33	36	34.31	26	33
70	32	95	32	21	32	34	26.09	3	32	125	32	36	33.33	24	32
68	31	95	31	21	31	33	25.00	3	31	120	31	36	32.35	24	31
66	30	90	30	20	30	33	23.91	3	30	115	30	35	31.37	22	30
65	29	90	29	20	29	29	22.83	3	29	110	29	35	30.39	22	29
62	28	80	28	20	28	29	21.74	3	28	110	28	35	29.41	22	28
61	27	80	27	20	27	28	20.65	3	27	100	27	34	28.43	22	27
57	26	80	26	17	26	20	19.57	2	26	98	26	34	27.45	22	26
53	25	80	25	17	25	8	18.48	2	25	98	25	34	26.47	22	25
50	24	80	24	17	24	6.5	17.39	2	24	95	24	34	25.49	20	24
44	23	80	23	16	23	6	16.30	2	23	90	23	33	24.51	20	23
38	22	80	22	15	22	5	15.22	2	22	89	22	32	23.53	20	22
31	21	80	21	15	21	5	14.13	2	21	78	21	32	22.55	19	21
31	20	75	20	15	20	5	13.04	2	20	75	20	31	21.57	18	20
30	19	75	19	13	19	4	11.96	2	19	70	19	30	20.59	18	19
29	18	75	18	13	18	3	10.87	2	18	70	18	29	19.61	15	18
28	17	75	17	13	17	3	9.78	2	17	66	17	27	18.63	15	17
26	16	70	16	13	16	3	8.70	2	16	65	16	26	17.65	15	16
21	15	65	15	13	15	3	7.61	2	15	64	15	26	16.67	12	15
15	14	65	14	13	14	3	6.52	2	14	63	14	25	15.69	11	14
10	13	65	13	12	13	3	5.43	2	13	60	13	24	14.71	9	13
9	12	60	12	11	12	3	4.35	2	12	59	12	24	13.73	9	12
8	11	60	11	11	11	3	3.26	2	11	54	11	23	12.75	7	11
7	10	50	10	11	10	3	2.17	2	10	52	10	21	11.76	6	10
5	9	50	9	11	9	3	1.09	2	9	45	9	21	10.78	3	9
3	8	49	8	10	8	2	bedrock	2	8	38	8	20	9.80	3	8
3	7	40	7	10	7	2	bedrock	2	7	36	7	20	8.82	3	7
3	6	35	6	10	6	2	bedrock	2	6	33	6	20	7.84	3	6
3	5	35	5	10	5	2	bedrock	2	5	33	5	19	6.86	3	5
3	4	30	4	10	4	2	bedrock	2	4	24	4	19	5.88	3	4
3	3	25	3	5	3	2	bedrock	2	3	16	3	17	4.90	3	3
3	2	10	2	4	2	2	bedrock	2	2	15	2	16	3.92	3	2
3	1	2	1	2	1	2	bedrock	2	1	10	1	16	2.94	3	1
												14	1.96		
												10	0.98		
D50 (mm)	95		140		27		74.00		4		140		51		40
D84 (mm)	220		450		73		146.00		7		99999		110		100

Pebble counts

Herd Creek	% finer	Johns Cr	% finer	Lt. Buckhorn Cr	% finer	Little Slate Cr	% finer	Lolo Creek	% finer	Marsh Creek	# of grains	% finer	Rapid River
(mm)		(mm)		(mm)		(mm)		(mm)		(mm)			(mm)
220	100	1000	100	900	100	800	100	230	100	512	0	100.00	380
180	99	720	99	900	99	800	99	192	99	360	1	98.95	320
172	98	620	98	900	98	770	98	153	98	256	0	98.95	270
172	97	600	97	475	97	770	97	151	97	180	6	92.63	250
160	96	530	96	475	96	770	96	141	96	128	8	84.21	240
160	95	480	95	475	95	550	95	140	95	90	9	74.74	222
148	94	465	94	460	94	550	94	139	94	64	16	57.89	210
137	93	430	93	460	93	485	93	132	93	45	21	35.79	195
132	92	420	92	460	92	460	92	132	92	32	22	12.63	193
130	91	405	91	460	91	450	91	127	91	22.5	6	6.32	187
122	90	400	90	450	90	450	90	127	90	16	2	4.21	181
115	89	370	89	450	89	430	89	126	89	11.25	1	3.16	180
112	88	365	88	450	88	430	88	125	88	8	1	2.11	175
112	87	360	87	430	87	430	87	124	87	5.625	0	2.11	172
110	86	350	86	430	86	410	86	123	86	4	0	2.11	170
108	85	340	85	430	85	405	85	123	85	<4	2	0.00	170
107	84	330	84	340	84	382	84	122	84				170
104	83	325	83	340	83	382	83	120	83				165
104	82	300	82	340	82	380	82	120	82				163
102	81	300	81	325	81	380	81	119	81				162
98	80	300	80	325	80	370	80	118	80				160
98	79	290	79	325	79	360	79	118	79				157
98	78	285	78	310	78	360	78	118	78				151
95	77	280	77	310	77	360	77	117	77				147
95	76	270	76	210	76	360	76	117	76				147
94	75	270	75	210	75	360	75	114	75				143
94	74	270	74	175	74	350	74	114	74				138
94	73	260	73	170	73	340	73	114	73				138
88	72	260	72	170	72	330	72	113	72				137
88	71	260	71	170	71	330	71	110	71				120
87	70	255	70	145	70	330	70	109	70				119
86	69	255	69	123	69	320	69	109	69				117
86	68	250	68	117	68	320	68	109	68				116
84	67	250	67	110	67	320	67	108	67				116
84	66	250	66	105	66	295	66	107	66				114
82	65	250	65	101	65	295	65	107	65				112
82	64	240	64	101	64	280	64	105	64				112
82	63	240	63	93	63	270	63	104	63				111
80	62	222	62	90	62	270	62	102	62				111
79	61	220	61	81	61	270	61	102	61				110
78	60	220	60	73	60	270	60	99	60				109
77	59	220	59	70	59	260	59	97	59				108
76	58	215	58	57	58	240	58	96	58				107
73	57	210	57	53	57	220	57	96	57				103
70	56	210	56	49	56	217	56	91	56				102
70	55	195	55	47	55	210	55	88	55				101
70	54	185	54	47	54	210	54	87	54				98
68	53	180	53	45	53	210	53	87	53				96
68	52	180	52	43	52	210	52	87	52				95
68	51	180	51	34	51	207	51	85	51				95
67	50	180	50	28	50	207	50	84	50				94
67	49	175	49	28	49	198	49	84	49				94
65	48	170	48	24	48	192	48	80	48				93
64	47	165	47	21	47	190	47	80	47				91
63	46	165	46	20	46	190	46	78	46				90
63	45	164	45	20	45	180	45	74	45				88
61	44	160	44	8	44	180	44	73	44				88
59	43	155	43	8	43	180	43	69	43				88
58	42	150	42	7	42	180	42	69	42				87
57	41	145	41	7	41	180	41	66	41				87
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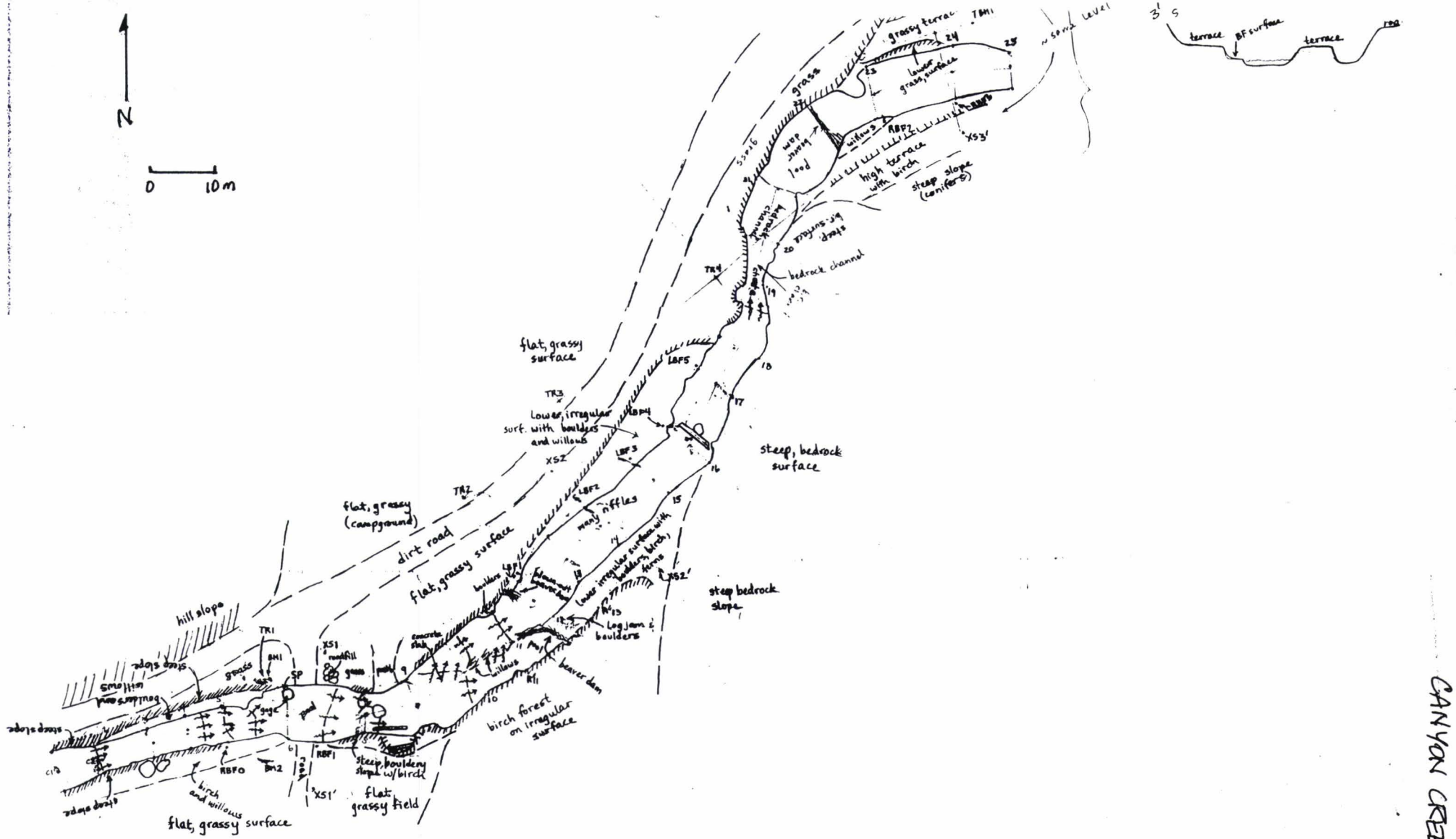
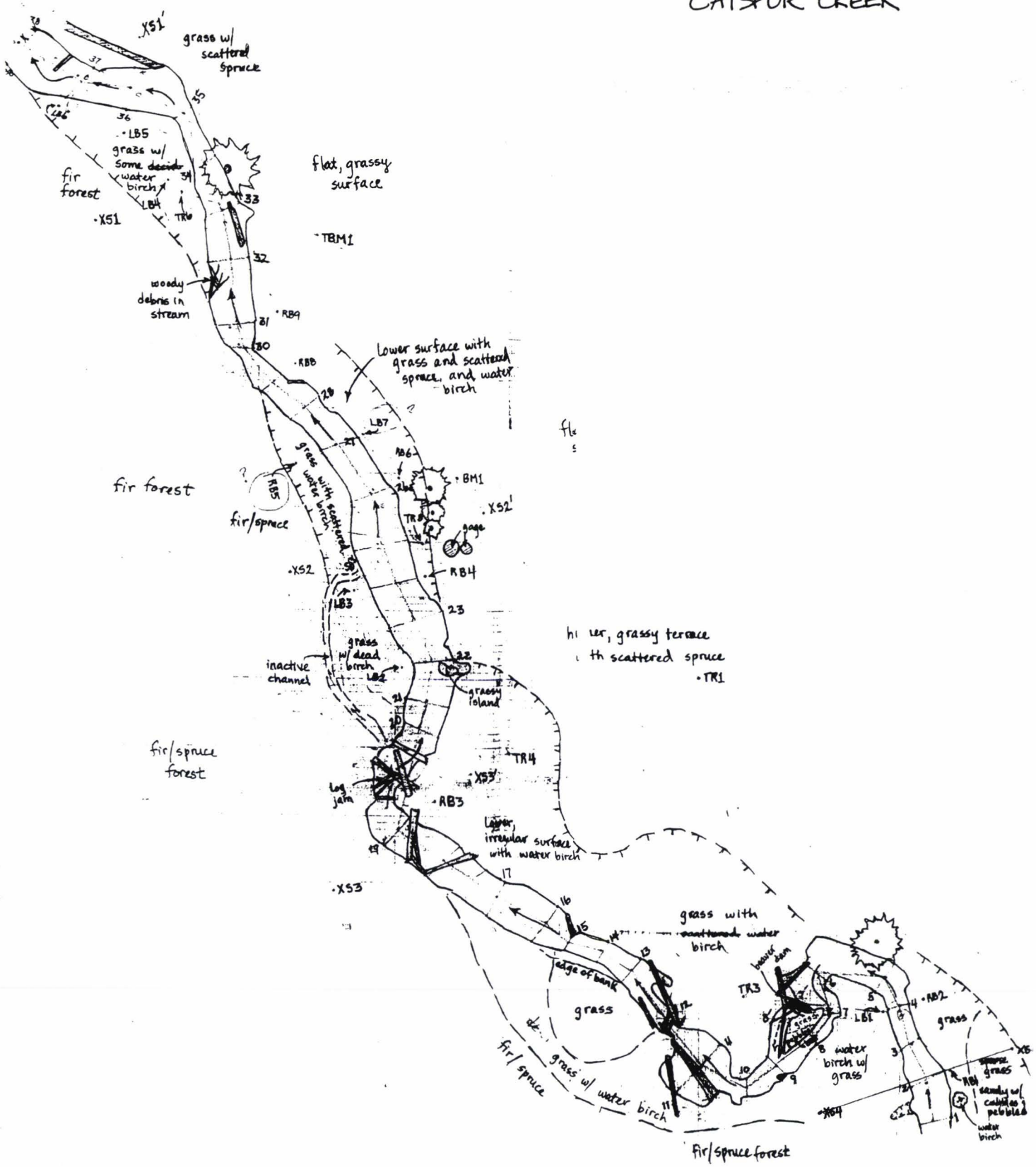
53	38	140	38	6	38	162	38	61	38				85
52	37	135	37	6	37	160	37	59	37				82
52	36	130	36	5	36	154	36	59	36				81
52	35	130	35	3	35	153	35	55	35				81
50	34	125	34	3	34	152	34	55	34				75
49	33	120	33	3	33	149	33	55	33				73
48	32	115	32	3	32	145	32	54	32				71
47	31	110	31	3	31	145	31	52	31				69
47	30	108	30	3	30	140	30	52	30				67
46	29	105	29	3	29	137	29	46	29				67
45	28	105	28	3	28	137	28	44	28				66
45	27	100	27	3	27	130	27	39	27				65
44	26	100	26	3	26	129	26	37	26				59
43	25	85	25	3	25	125	25	37	25				56
43	24	76	24	3	24	125	24	32	24				56
43	23	70	23	3	23	120	23	32	23				54
43	22	68	22	3	22	116	22	31	22				53
43	21	66	21	3	21	114	21	31	21				53
39	20	66	20	3	20	105	20	30	20				50
39	19	64	19	3	19	103	19	22	19				49
38	18	59	18	3	18	100	18	17	18				48
38	17	55	17	3	17	97	17	17	17				48
37	16	54	16	3	16	97	16	15	16				47
33	15	50	15	3	15	95	15	14	15				43
33	14	40	14	3	14	90	14	9	14				42
33	13	38	13	3	13	85	13	5	13				42
31	12	34	12	3	12	78	12	5	12				42
29	11	32	11	3	11	71	11	3	11				39
28	10	30	10	3	10	68	10	3	10				38
27	9	28	9	3	9	62	9	3	9				38
25	8	15	8	3	8	60	8	3	8				37
23	7	10	7	3	7	44	7	3	7				36
22	6	9	6	3	6	38	6	3	6				36
20	5	1	5	3	5	13	5	3	5				34
19	4	1	4	3	4	2	4	3	4				32
18	3	1	3	3	3	2	3	3	3				29
18	2	1	2	1	2	2	2	3	2				26
17	1	1	1	1	1	2	1	3	1				21
	67		180		28		207		84			57	
	107		330		340		382		122			127	

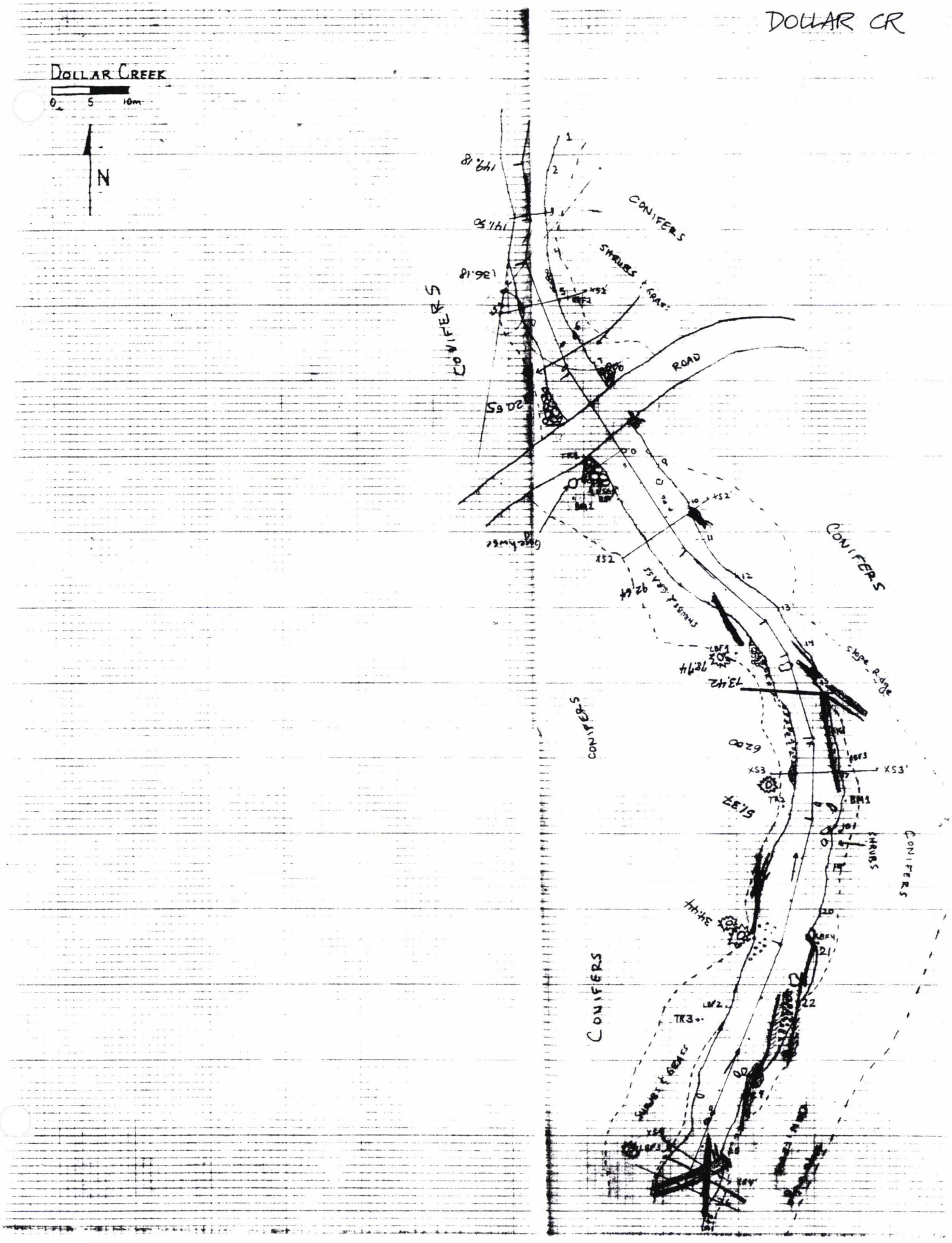


CANYON CREEK

CATSPUR CREEK



DOLLAR CR


DOLLAR CREEK
0 5 10m
N
CONIFERS
SHRUBS & GRASS
ROAD
CONIFERS
CONIFERS
CONIFERS
CONIFERS
SHRUBS
SHRUBS & GRASS
XS2
XS2'
XS3
XS3'
TR1
TR2
TR3
BM1
BM2
BM3
BM4
LOG1
LOG2
LOG3
LOG4
LOG5
LOG6
LOG7
LOG8
LOG9
LOG10
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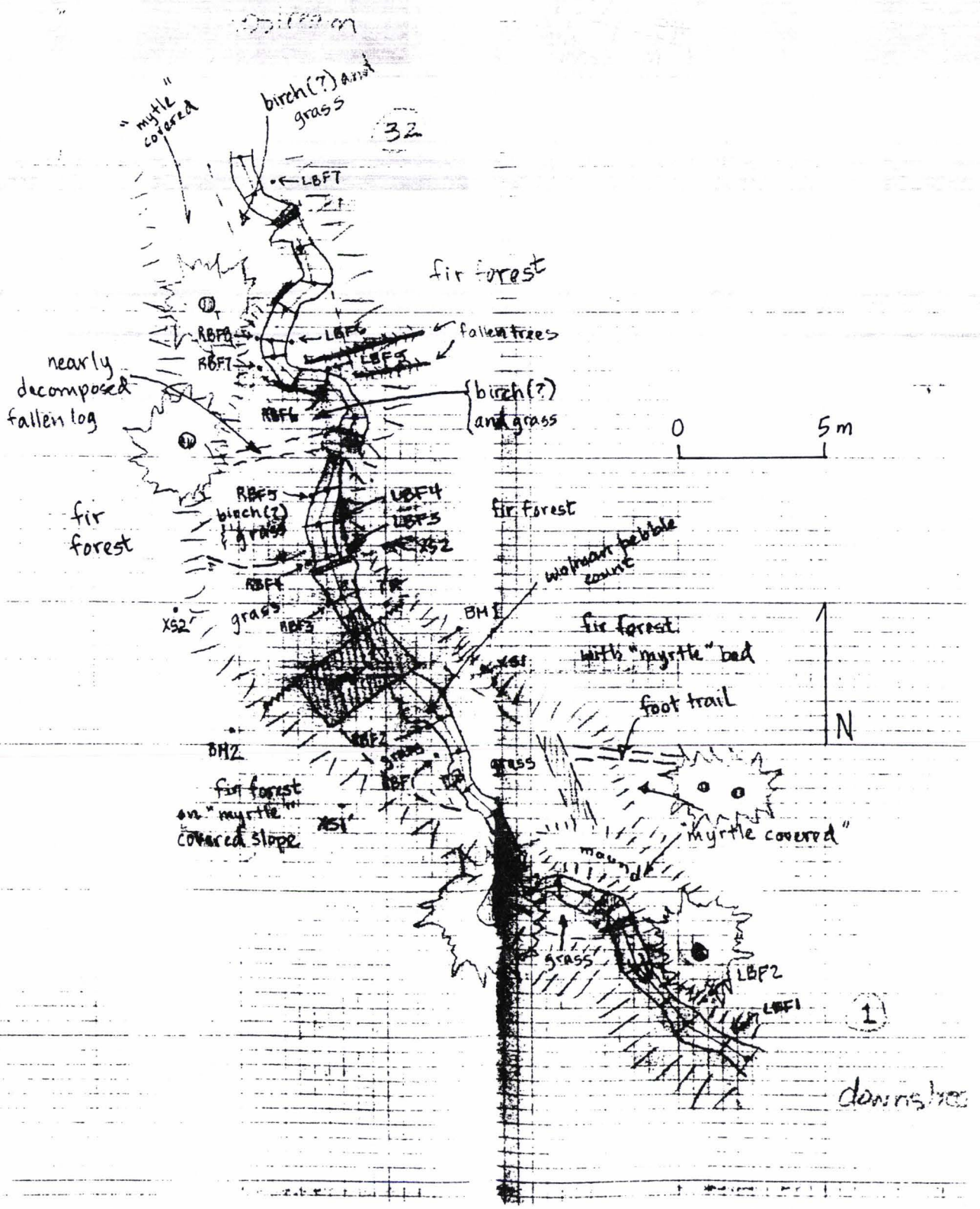
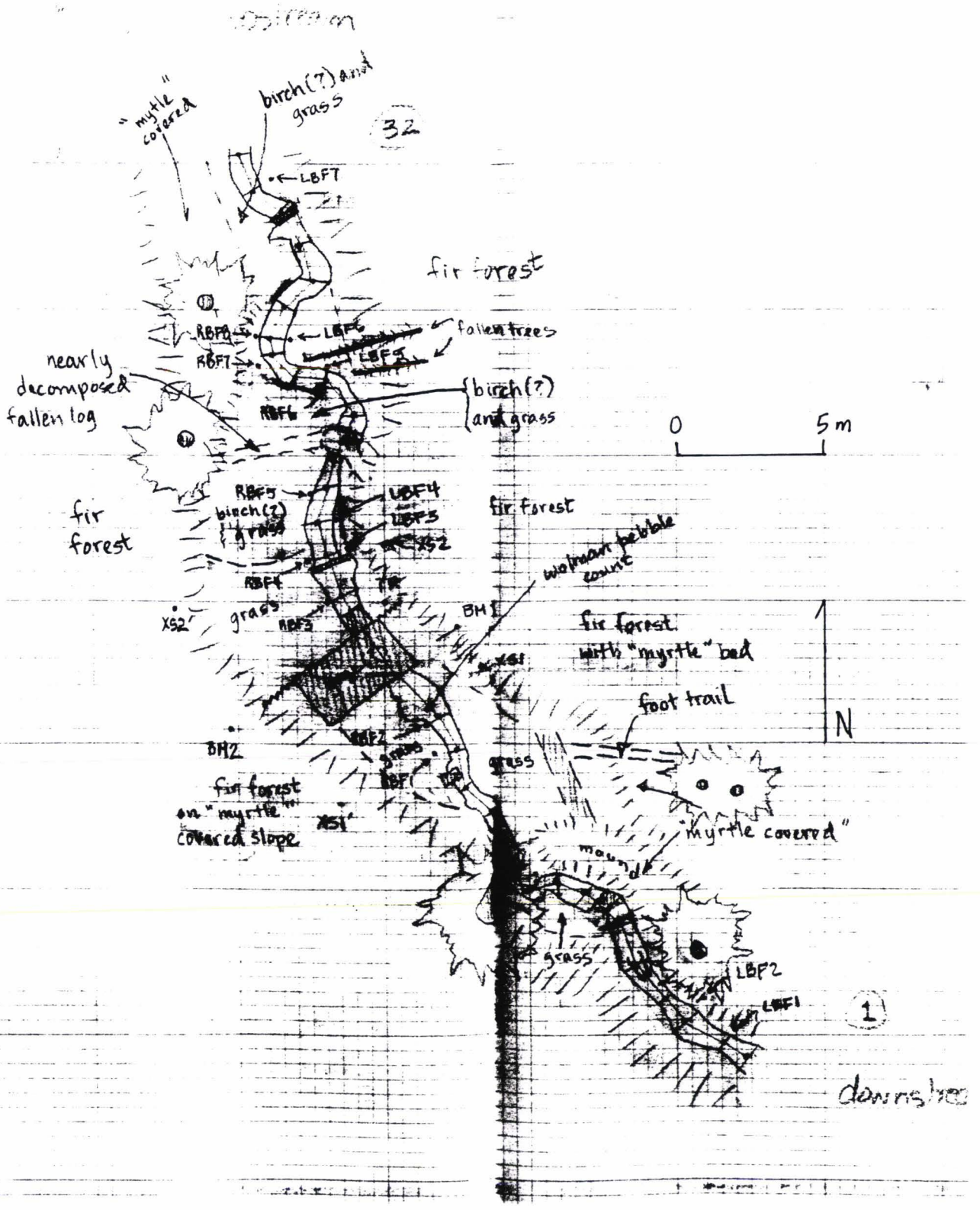
LOG39
LOG40

EGGERS CREEK

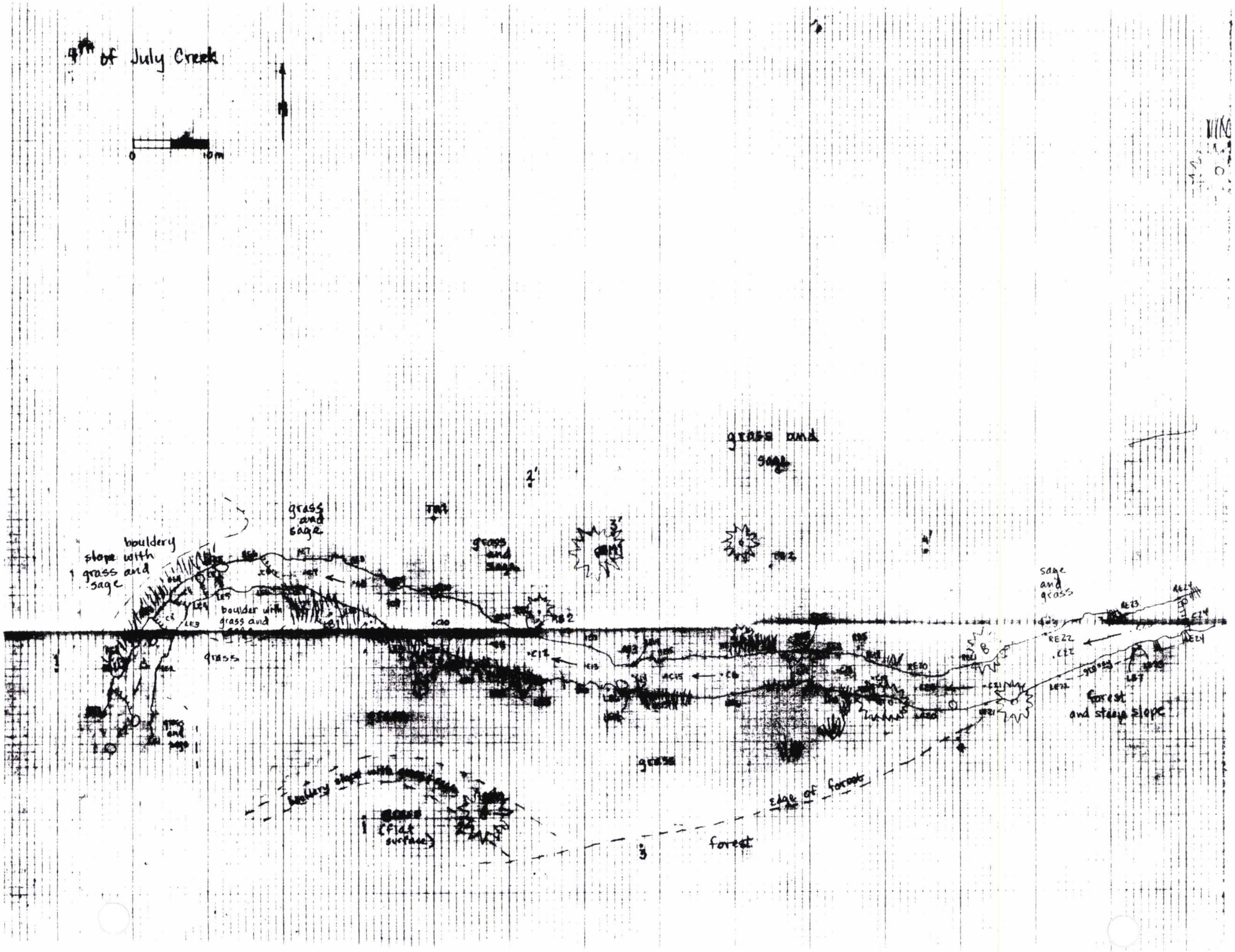


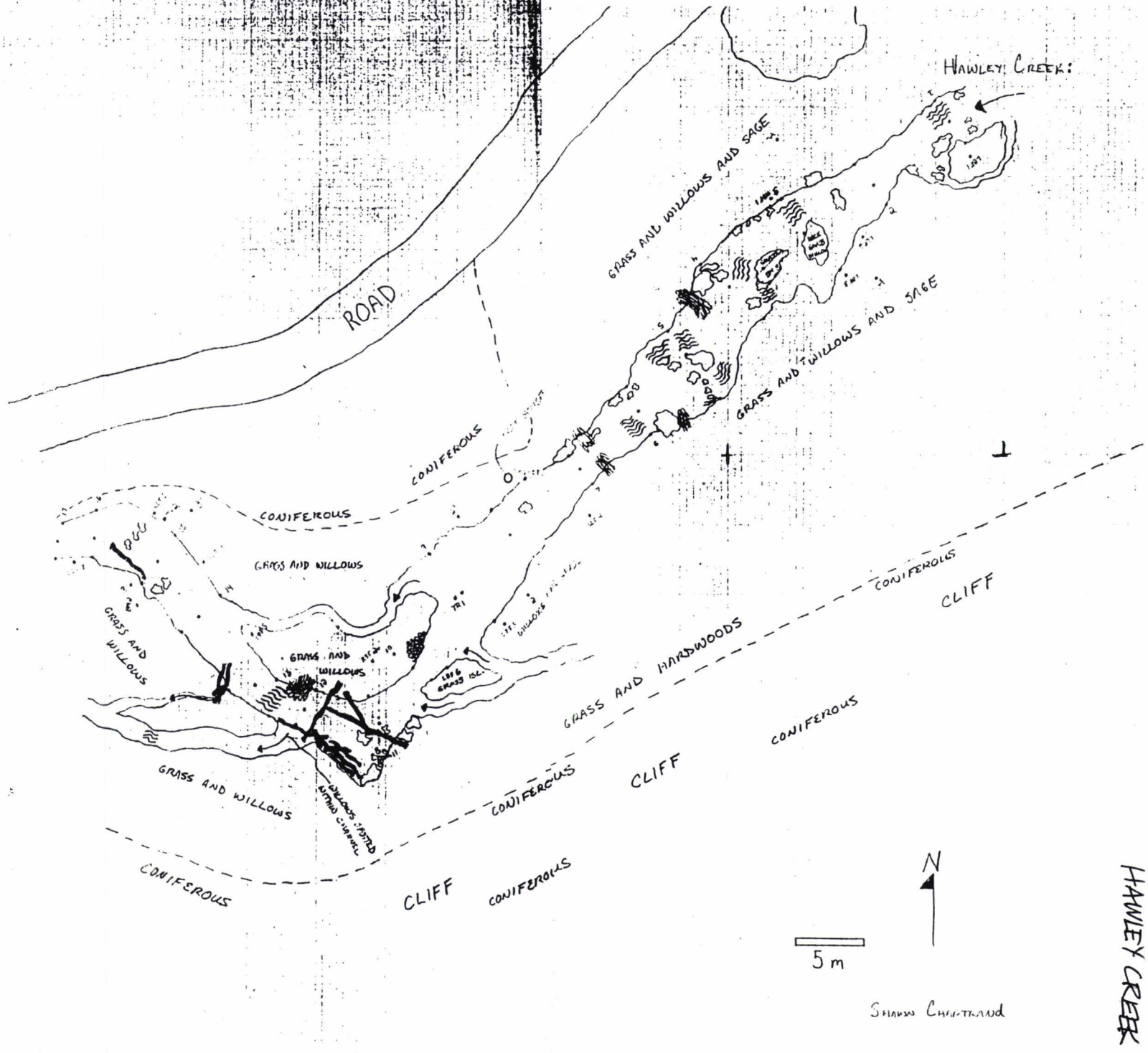
EGGERS CREEK

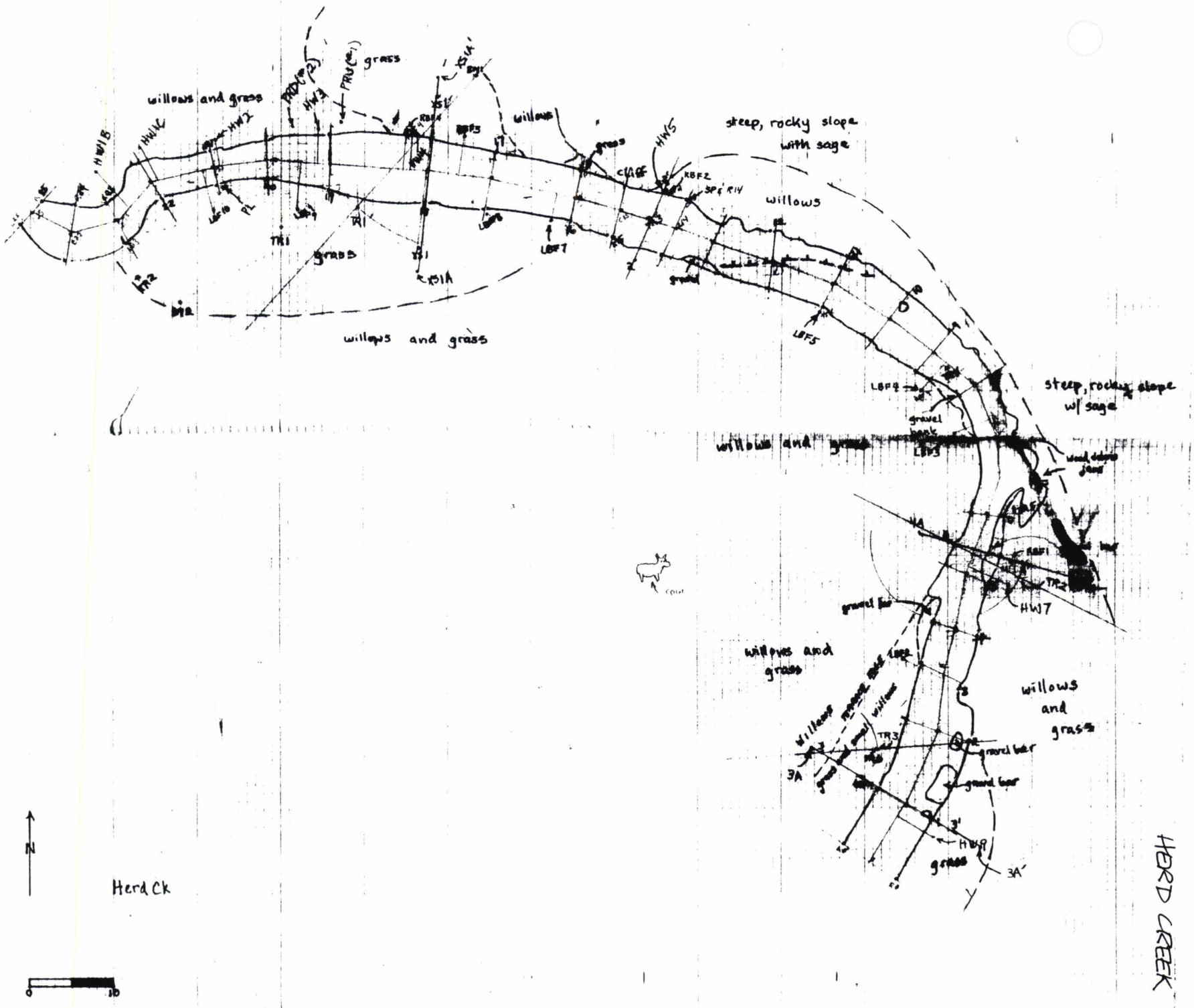


FISH CREEK (1/2)

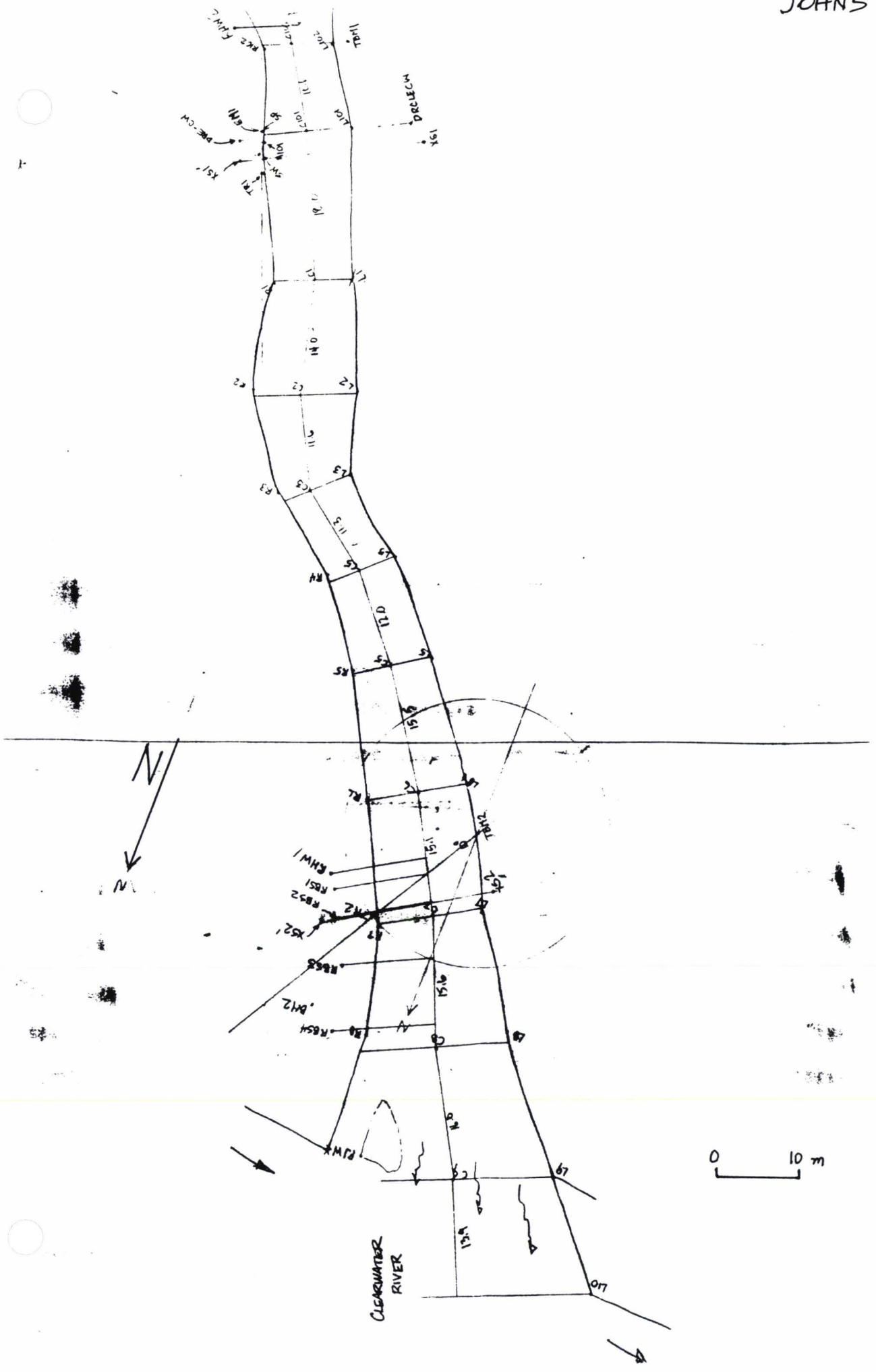
FISH CREEK (2/2


4th of July Creek
0
10m
boulder slope with grass and sage
grass and sage
boulder with grass and
grass
grass and sage
sage and grass
forest and steep slope
grass
boulder slope with
grass
(flat surface)
edge of forest
forest


HAWLEY CREEK
ROAD
GRASS AND WILLOWS AND SAGE
GRASS AND WILLOWS AND SAGE
CONIFEROUS
CONIFEROUS
GRASS AND WILLOWS
GRASS AND WILLOWS
GRASS AND WILLOWS
GRASS AND WILLOWS
GRASS AND HARDWOODS
CONIFEROUS
CLIFF
CONIFEROUS
CLIFF
CONIFEROUS
CONIFEROUS
CLIFF
CONIFEROUS
N
5 m
SHARON CHRISTMAND
HAWLEY CREEK


willows and grass
grass
steep, rocky slope with sage
willows
cliff
willows and grass
steep, rocky slope w/ sage
gravel bank
willows and grass
gravel bar
willows and grass
willows and grass
gravel bar
gravel bar
grass
N
Herd Ck
0
10
HERD CREEK

JOHNS CREEK (1/2)



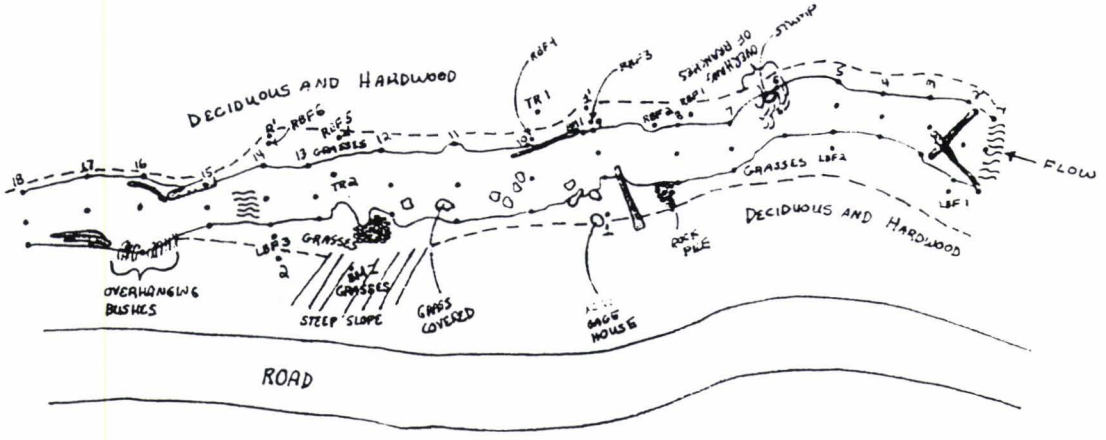
JOHNS CREEK (2/2

SQUAW CREEK 2
SALMON NATIONAL FOREST

5 m

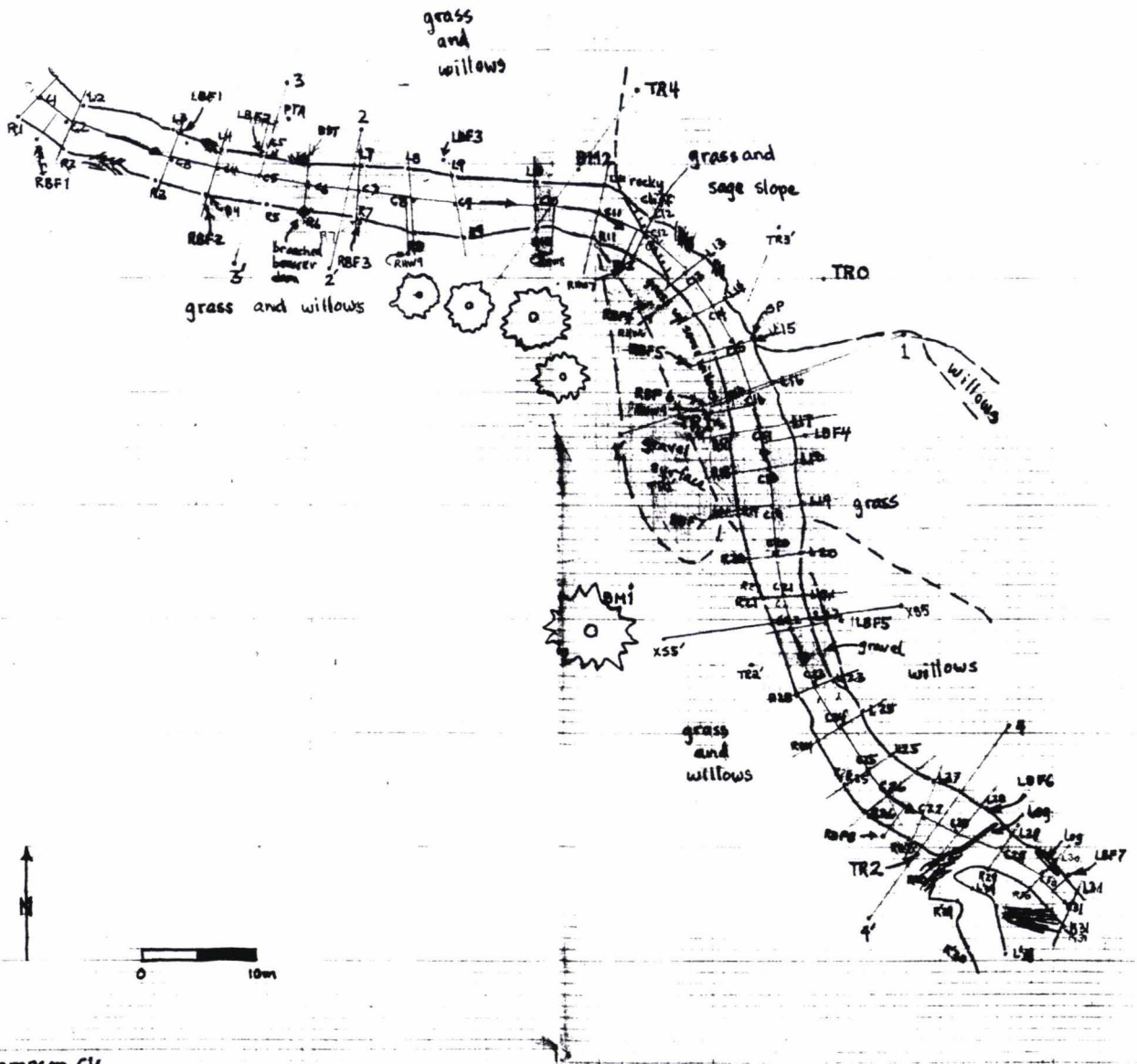
N

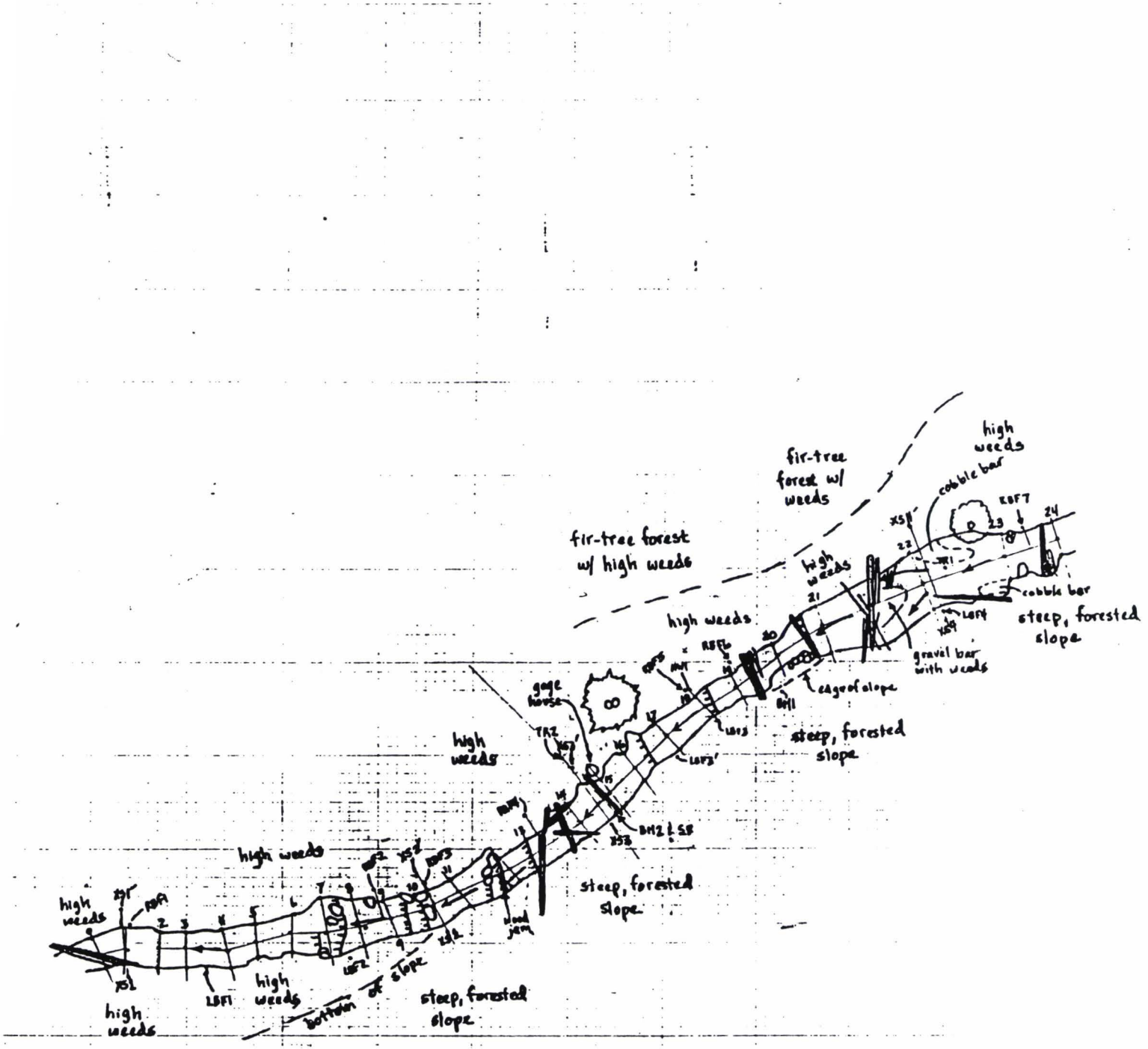
LOG
RIFFLE
ROCK
STUMP



= old beaver dam or wood jam

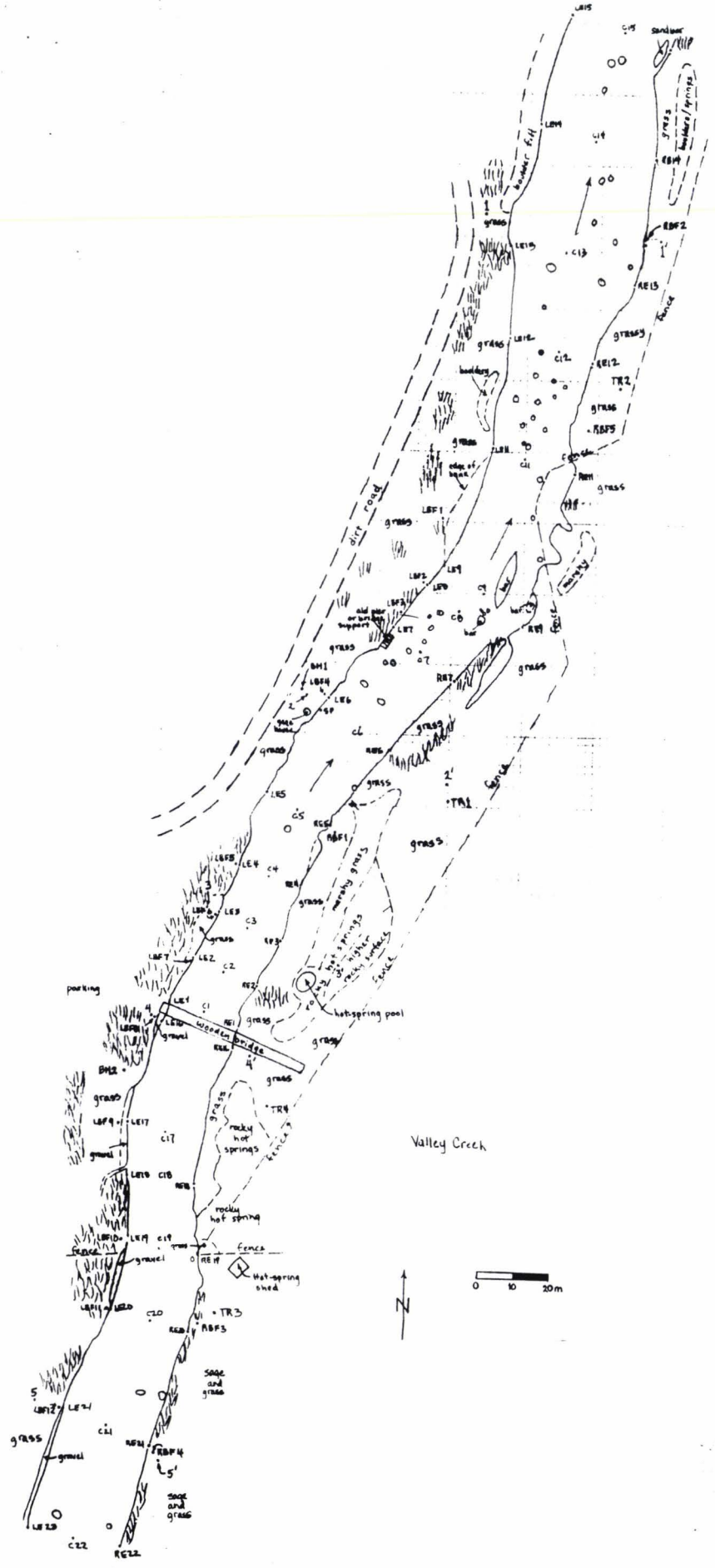
= pine

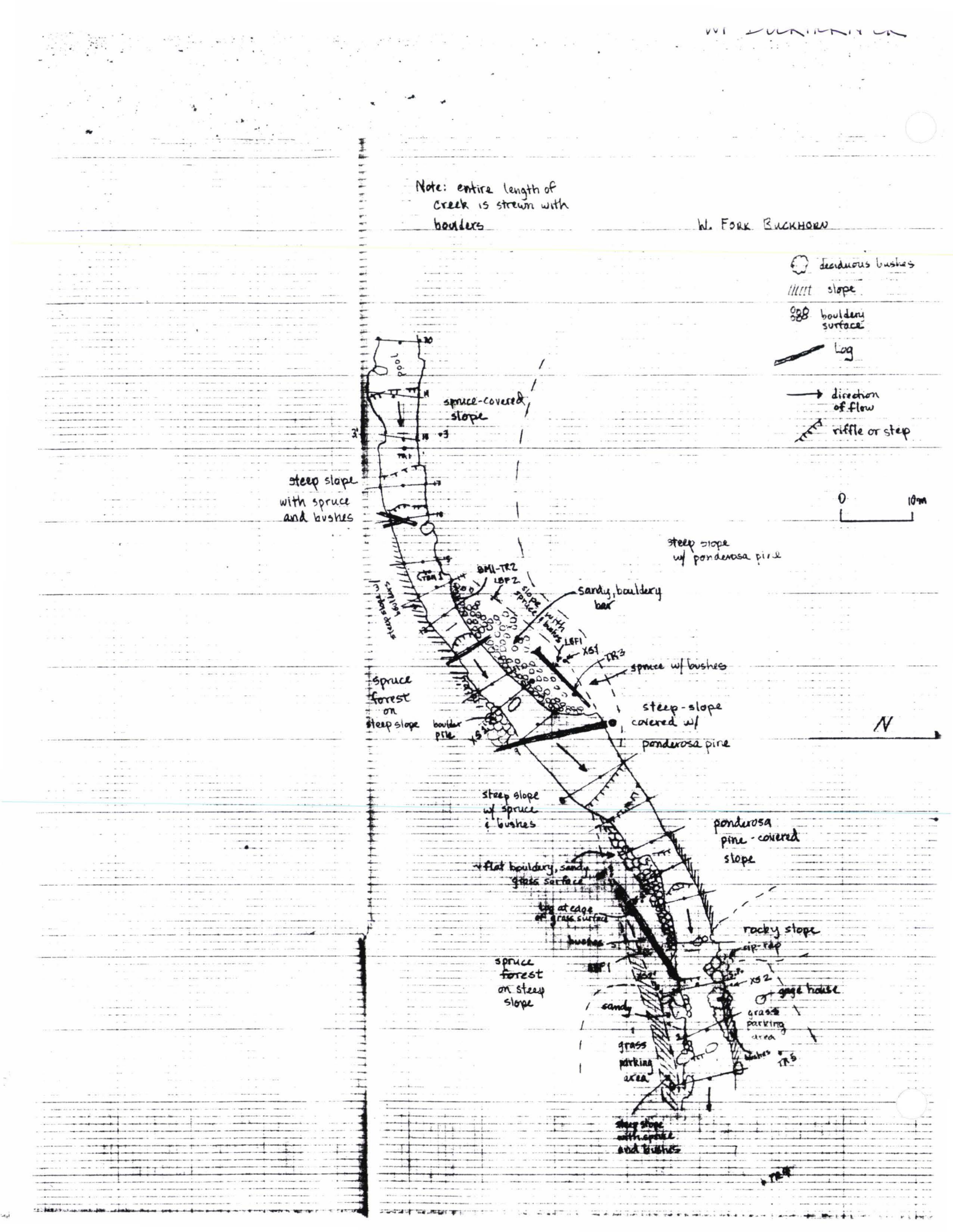




TRAPPER CREEK

VALLEY CREEK




Note: entire length of creek is strewn with boulders
W. Fork Buckhorn
deciduous bushes
slope
bouldery surface
Log
direction of flow
riffle or step
0
10m
N
pool
spruce-covered slope
steep slope with spruce and bushes
steep slope w/ ponderosa pine
sandy, bouldery bar
BM1-TR2
LBP2
LBF1
XS1
TR3
spruce w/ bushes
spruce forest on steep slope
boulder pile
XS3
steep-slope covered w/ ponderosa pine
steep slope w/ spruce & bushes
ponderosa pine-covered slope
flat bouldery, sandy grass surface
top of edge of grass surface
bushes
rocky slope
rip-rap
spruce forest on steep slope
LBF1
XS2
gage house
sandy
grass parking area
TR5
steep slope with spruce and bushes

Pebble counts

Blackmare Cr	% finer	Canyon Cr	% finer	Catspur Cr	% finer	Dollar Creek	% finer	Eggers Cr	% finer	Fish Cr	% finer	4 July Creek	% finer	Hawley Cr	% finer
(mm)		(mm)		(mm)		(mm)		(mm)		(mm)		(mm)		(mm)	
365	100	1000	100	180	100	401	100.00	89	100	99999	100	600	100	340	100
323	99	1000	99	170	99	378	98.91	70	99	99999	99	600	99.02	340	99
300	98	1000	98	134	98	378	97.83	25	98	99999	98	250	98.04	340	98
296	97	1000	97	110	97	308	96.74	20	97	99999	97	250	97.06	340	97
290	96	660	96	105	96	211	95.65	20	96	99999	96	240	96.08	340	96
278	95	660	95	102	95	188	94.57	12	95	99999	95	182	95.10	260	95
267	94	660	94	100	94	184	93.48	10	94	99999	94	174	94.12	260	94
260	93	650	93	100	93	182	92.39	10	93	99999	93	170	93.14	260	93
254	92	650	92	90	92	175	91.30	9	92	99999	92	150	92.16	160	92
254	91	550	91	85	91	171	90.22	9	91	99999	91	142	91.18	150	91
252	90	550	90	80	90	164	89.13	8	90	99999	90	139	90.20	140	90
250	89	500	89	80	89	155	88.04	8	89	99999	89	129	89.22	120	89
248	88	500	88	80	88	150	86.96	8	88	99999	88	120	88.24	110	88
245	87	460	87	75	87	150	85.87	8	87	99999	87	120	87.25	110	87
230	86	460	86	75	86	146	84.78	7	86	99999	86	115	86.27	100	86
222	85	450	85	75	85	145	83.70	7	85	99999	85	112	85.29	100	85
220	84	450	84	73	84	144	82.61	7	84	99999	84	110	84.31	100	84
214	83	450	83	70	83	132	81.52	7	83	99999	83	110	83.33	99	83
214	82	420	82	68	82	130	80.43	7	82	99999	82	105	82.35	95	82
208	81	400	81	67	81	130	79.35	6	81	99999	81	100	81.37	91	81
200	80	400	80	65	80	116	78.26	6	80	99999	80	100	80.39	90	80
200	79	400	79	62	79	113	77.17	6	79	99999	79	99	79.41	86	79
190	78	380	78	57	78	113	76.09	6	78	99999	78	98	78.43	85	78
185	77	380	77	56	77	107	75.00	5	77	99999	77	98	77.45	85	77
184	76	350	76	55	76	104	73.91	5	76	99999	76	93	76.47	82	76
180	75	350	75	55	75	103	72.83	5	75	99999	75	93	75.49	80	75
180	74	310	74	50	74	98	71.74	5	74	99999	74	91	74.51	78	74
175	73	310	73	50	73	97	70.65	5	73	99999	73	89	73.53	75	73
175	72	300	72	45	72	97	69.57	5	72	99999	72	88	72.55	72	72
170	71	300	71	40	71	94	68.48	5	71	99999	71	87	71.57	71	71
167	70	300	70	40	70	94	67.39	5	70	99999	70	84	70.59	70	70
166	69	250	69	37	69	92	66.30	5	69	700	69	80	69.61	70	69
163	68	240	68	34	68	91	65.22	5	68	700	68	78	68.63	70	68
163	67	230	67	33	67	91	64.13	5	67	650	67	73	67.65	68	67
150	66	210	66	33	66	91	63.04	5	66	650	66	70	66.67	66	66
146	65	190	65	33	65	90	61.96	5	65	600	65	69	65.69	60	65
146	64	190	64	32	64	90	60.87	5	64	550	64	67	64.71	60	64
140	63	190	63	32	63	89	59.78	5	63	500	63	66	63.73	58	63
139	62	180	62	31	62	86	58.70	5	62	470	62	65	62.75	52	62
133	61	180	61	30	61	81	57.61	5	61	470	61	61	61.76	52	61
132	60	170	60	30	60	81	56.52	5	60	450	60	59	60.78	50	60
128	59	160	59	30	59	79	55.43	5	59	410	59	58	59.80	48	59
126	58	160	58	30	58	78	54.35	5	58	400	58	57	58.82	47	58
114	57	150	57	30	57	78	53.26	4	57	370	57	56	57.84	47	57
106	56	150	56	30	56	78	52.17	4	56	360	56	56	56.86	46	56
103	55	150	55	30	55	77	51.09	4	55	350	55	55	55.88	46	55
100	54	150	54	28	54	74	50.00	4	54	350	54	54	54.90	44	54
99	53	150	53	28	53	73	48.91	4	53	340	53	53	53.92	42	53
98	52	140	52	27	52	72	47.83	4	52	330	52	52	52.94	41	52
97	51	140	51	27	51	72	46.74	4	51	330	51	52	51.96	40	51
95	50	140	50	27	50	70	45.65	4	50	330	50	52	50.98	40	50
94	49	140	49	26	49	70	44.57	4	49	330	49	51	50.00	36	49
93	48	140	48	26	48	68	43.48	4	48	320	48	50	49.02	36	48
90	47	140	47	26	47	65	42.39	4	47	320	47	50	48.04	35	47
90	46	135	46	25	46	60	41.30	3	46	320	46	50	47.06	35	46
85	45	132	45	25	45	58	40.22	3	45	310	45	48	46.08	33	45
85	44	130	44	25	44	58	39.13	3	44	300	44	48	45.10	33	44
84	43	130	43	25	43	57	38.04	3	43	260	43	47	44.12	32	43
83	42	130	42	25	42	54	36.96	3	42	260	42	44	43.14	31	42
83	41	120	41	24	41	52	35.87	3	41	250	41	44	42.16	31	41
83	40	111	40	24	40	50	34.78	3	40	250	40	41	41.18	31	40
82	39	111	39	23	39	49	33.70	3	39	230	39	40	40.20	30	39
80	38	110	38	23	38	48	32.61	3	38	200	38	40	39.22	30	38
80	37	110	37	23	37	47	31.52	3	37	170	37	40	38.24	29	37
80	36	110	36	22	36	41	30.43	3	36	170	36	40	37.25	28	36
79	35	110	35	22	35	40	29.35	3	35	140	35	37	36.27	27	35
79	34	100	34	22	34	36	28.26	3	34	140	34	37	35.29	26	34
75	33	95	33	22	33	35.7	27.17	3	33	132	33	36	34.31	26	33
70	32	95	32	21	32	34	26.09	3	32	125	32	36	33.33	24	32
68	31	95	31	21	31	33	25.00	3	31	120	31	36	32.35	24	31
66	30	90	30	20	30	33	23.91	3	30	115	30	35	31.37	22	30
65	29	90	29	20	29	29	22.83	3	29	110	29	35	30.39	22	29
62	28	80	28	20	28	29	21.74	3	28	110	28	35	29.41	22	28
61	27	80	27	20	27	28	20.65	3	27	100	27	34	28.43	22	27
57	26	80	26	17	26	20	19.57	2	26	98	26	34	27.45	22	26
53	25	80	25	17	25	8	18.48	2	25	98	25	34	26.47	22	25
50	24	80	24	17	24	6.5	17.39	2	24	95	24	34	25.49	20	24
44	23	80	23	16	23	6	16.30	2	23	90	23	33	24.51	20	23
38	22	80	22	15	22	5	15.22	2	22	89	22	32	23.53	20	22
31	21	80	21	15	21	5	14.13	2	21	78	21	32	22.55	19	21
31	20	75	20	15	20	5	13.04	2	20	75	20	31	21.57	18	20
30	19	75	19	13	19	4	11.96	2	19	70	19	30	20.59	18	19
29	18	75	18	13	18	3	10.87	2	18	70	18	29	19.61	15	18
28	17	75	17	13	17	3	9.78	2	17	66	17	27	18.63	15	17
26	16	70	16	13	16	3	8.70	2	16	65	16	26	17.65	15	16
21	15	65	15	13	15	3	7.61	2	15	64	15	26	16.67	12	15
15	14	65	14	13	14	3	6.52	2	14	63	14	25	15.69	11	14
10	13	65	13	12	13	3	5.43	2	13	60	13	24	14.71	9	13
9	12	60	12	11	12	3	4.35	2	12	59	12	24	13.73	9	12
8	11	60	11	11	11	3	3.26	2	11	54	11	23	12.75	7	11
7	10	50	10	11	10	3	2.17	2	10	52	10	21	11.76	6	10
5	9	50	9	11	9	3	1.09	2	9	45	9	21	10.78	3	9
3	8	49	8	10	8	2	bedrock	2	8	38	8	20	9.80	3	8
3	7	40	7	10	7	2	bedrock	2	7	36	7	20	8.82	3	7
3	6	35	6	10	6	2	bedrock	2	6	33	6	20	7.84	3	6
3	5	35	5	10	5	2	bedrock	2	5	33	5	19	6.86	3	5
3	4	30	4	10	4	2	bedrock	2	4	24	4	19	5.88	3	4
3	3	25	3	5	3	2	bedrock	2	3	16	3	17	4.90	3	3
3	2	10	2	4	2	2	bedrock	2	2	15	2	16	3.92	3	2
3	1	2	1	2	1	2	bedrock	2	1	10	1	16	2.94	3	1
												14	1.96		
												10	0.98		
D50 (mm)	95		140		27		74.00		4		140		51		40
D84 (mm)	220		450		73		146.00		7		99999		110		100

Pebble counts

Herd Creek	% finer	Johns Cr	% finer	Lt. Buckhorn Cr	% finer	Little Slate Cr	% finer	Lolo Creek	% finer	Marsh Creek	# of grains	% finer
(mm)		(mm)		(mm)		(mm)		(mm)		(mm)		
220	100	1000	100	900	100	800	100	230	100	512	0	100.00
180	99	720	99	900	99	800	99	192	99	360	1	98.95
172	98	620	98	900	98	770	98	153	98	256	0	98.95
172	97	600	97	475	97	770	97	151	97	180	6	92.63
160	96	530	96	475	96	770	96	141	96	128	8	84.21
160	95	480	95	475	95	550	95	140	95	90	9	74.74
148	94	465	94	460	94	550	94	139	94	64	16	57.89
137	93	430	93	460	93	485	93	132	93	45	21	35.79
132	92	420	92	460	92	460	92	132	92	32	22	12.63
130	91	405	91	460	91	450	91	127	91	22.5	6	6.32
122	90	400	90	450	90	450	90	127	90	16	2	4.21
115	89	370	89	450	89	430	89	126	89	11.25	1	3.16
112	88	365	88	450	88	430	88	125	88	8	1	2.11
112	87	360	87	430	87	430	87	124	87	5.625	0	2.11
110	86	350	86	430	86	410	86	123	86	4	0	2.11
108	85	340	85	430	85	405	85	123	85	<4	2	0.00
107	84	330	84	340	84	382	84	122	84			
104	83	325	83	340	83	382	83	120	83			
104	82	300	82	340	82	380	82	120	82			
102	81	300	81	325	81	380	81	119	81			
98	80	300	80	325	80	370	80	118	80			
98	79	290	79	325	79	360	79	118	79			
98	78	285	78	310	78	360	78	118	78			
95	77	280	77	310	77	360	77	117	77			
95	76	270	76	210	76	360	76	117	76			
94	75	270	75	210	75	360	75	114	75			
94	74	270	74	175	74	350	74	114	74			
94	73	260	73	170	73	340	73	114	73			
88	72	260	72	170	72	330	72	113	72			
88	71	260	71	170	71	330	71	110	71			
87	70	255	70	145	70	330	70	109	70			
86	69	255	69	123	69	320	69	109	69			
86	68	250	68	117	68	320	68	109	68			
84	67	250	67	110	67	320	67	108	67			
84	66	250	66	105	66	295	66	107	66			
82	65	250	65	101	65	295	65	107	65			
82	64	240	64	101	64	280	64	105	64			
82	63	240	63	93	63	270	63	104	63			
80	62	222	62	90	62	270	62	102	62			
79	61	220	61	81	61	270	61	102	61			
78	60	220	60	73	60	270	60	99	60			
77	59	220	59	70	59	260	59	97	59			
76	58	215	58	57	58	240	58	96	58			
73	57	210	57	53	57	220	57	96	57			
70	56	210	56	49	56	217	56	91	56			
70	55	195	55	47	55	210	55	88	55			
70	54	185	54	47	54	210	54	87	54			
68	53	180	53	45	53	210	53	87	53			
68	52	180	52	43	52	210	52	87	52			
68	51	180	51	34	51	207	51	85	51			
67	50	180	50	28	50	207	50	84	50			
67	49	175	49	28	49	198	49	84	49			
65	48	170	48	24	48	192	48	80	48			
64	47	165	47	21	47	190	47	80	47			
63	46	165	46	20	46	190	46	78	46			
63	45	164	45	20	45	180	45	74	45			
61	44	160	44	8	44	180	44	73	44			
59	43	155	43	8	43	180	43	69	43			
58	42	150	42	7	42	180	42	69	42			
57	41	145	41	7	41	180	41	66	41			
54	40	140	40	7	40	180	40	64	40			
54	39	140	39	6	39	175	39	62	39			
53	38	140	38	6	38	162	38	61	38			
52	37	135	37	6	37	160	37	59	37			
52	36	130	36	5	36	154	36	59	36			
52	35	130	35	3	35	153	35	55	35			
50	34	125	34	3	34	152	34	55	34			
49	33	120	33	3	33	149	33	55	33			
48	32	115	32	3	32	145	32	54	32			
47	31	110	31	3	31	145	31	52	31			
47	30	108	30	3	30	140	30	52	30			
46	29	105	29	3	29	137	29	46	29			
45	28	105	28	3	28	137	28	44	28			
45	27	100	27	3	27	130	27	39	27			
44	26	100	26	3	26	129	26	37	26			
43	25	85	25	3	25	125	25	37	25			
43	24	76	24	3	24	125	24	32	24			
43	23	70	23	3	23	120	23	32	23			
43	22	68	22	3	22	116	22	31	22			
43	21	66	21	3	21	114	21	31	21			
39	20	66	20	3	20	105	20	30	20			
39	19	64	19	3	19	103	19	22	19			
38	18	59	18	3	18	100	18	17	18			
38	17	55	17	3	17	97	17	17	17			
37	16	54	16	3	16	97	16	15	16			
33	15	50	15	3	15	95	15	14	15			
33	14	40	14	3	14	90	14	9	14			
33	13	38	13	3	13	85	13	5	13			
31	12	34	12	3	12	78	12	5	12			
29	11	32	11	3	11	71	11	3	11			
28	10	30	10	3	10	68	10	3	10			
27	9	28	9	3	9	62	9	3	9			
25	8	15	8	3	8	60	8	3	8			
23	7	10	7	3	7	44	7	3	7			
22	6	9	6	3	6	38	6	3	6			
20	5	1	5	3	5	13	5	3	5			
19	4	1	4	3	4	2	4	3	4			
18	3	1	3	3	3	2	3	3	3			
18	2	1	2	1	2	2	2	3	2			
17	1	1	1	1	1	2	1	3	1			
	67		180		28		207		84			57
	107		330		340		382		122			127

Pebble counts

Rapid River	% finer	Red River	% finer	SF Red River	% finer	Squaw Creek	% finer	Squaw Creek	% finer	Thompson Ck	% finer	Trapper Creek	% finer	Valley Creek	% finer
(mm)		(mm)		(mm)		(mm)		(mm)		(mm)		(mm)		(mm)	
380	100	176	100	370	100	144	100	256	100	225	100	287	100	154	100.0
320	99	147	99	265	99	140	99.04	226	99.04	190	99	252	99.04	144	98.8
270	98	138	98	260	98	140	98.08	200	98.08	190	98	252	98.08	136	97.5
250	97	133	97	230	97	140	97.12	157	97.12	190	97	234	97.12	134	96.3
240	96	118	96	200	96	132	96.15	150	96.15	190	96	168	96.15	130	95.1
222	95	116	95	200	95	114	95.19	135	95.19	190	95	163	95.19	122	93.8
210	94	114	94	200	94	112	94.23	133	94.23	180	94	145	94.23	118	92.6
195	93	113	93	200	93	89	93.27	117	93.27	180	93	145	93.27	110	91.4
193	92	113	92	190	92	83	92.31	93	92.31	140	92	143	92.31	107	90.1
187	91	112	91	180	91	77	91.35	88	91.35	130	91	140	91.35	106	88.9
181	90	110	90	165	90	74	90.38	84	90.38	130	90	138	90.38	106	87.7
180	89	105	89	165	89	74	89.42	82	89.42	128	89	134	89.42	105	86.4
175	88	101	88	160	88	66	88.46	82	88.46	120	88	133	88.46	101	85.2
172	87	100	87	155	87	64	87.50	82	87.50	119	87	128	87.50	100	84.0
170	86	99	86	150	86	63	86.54	78	86.54	114	86	125	86.54	95	82.7
170	85	98	85	150	85	62	85.58	76	85.58	110	85	125	85.58	95	81.5
170	84	93	84	150	84	62	84.62	75	84.62	110	84	124	84.62	95	80.2
165	83	92	83	150	83	62	83.65	72	83.65	109	83	120	83.65	94	79.0
163	82	91	82	150	82	62	82.69	72	82.69	106	82	119	82.69	89	77.8
162	81	89	81	150	81	54	81.73	71	81.73	105	81	114	81.73	84	76.5
160	80	87	80	150	80	52	80.77	71	80.77	102	80	114	80.77	84	75.3
157	79	87	79	144	79	52	79.81	70	79.81	102	79	104	79.81	82	74.1
151	78	86	78	140	78	50	78.85	69	78.85	100	78	100	78.85	78	72.8
147	77	83	77	133	77	49	77.88	69	77.88	100	77	100	77.88	75	71.6
147	76	82	76	133	76	48	76.92	68	76.92	100	76	99	76.92	74	70.4
143	75	81	75	125	75	46	75.96	67	75.96	98	75	99	75.96	70	69.1
138	74	80	74	120	74	46	75.00	65	75.00	97	74	98	75.00	67	67.9
138	73	79	73	120	73	45	74.04	65	74.04	95	73	97	74.04	64	66.7
137	72	79	72	120	72	44	73.08	64	73.08	93	72	97	73.08	63	65.4
120	71	78	71	120	71	43	72.12	64	72.12	91	71	95	72.12	62	64.2
119	70	78	70	115	70	42	71.15	62	71.15	87	70	93	71.15	61	63.0
117	69	78	69	114	69	42	70.19	61	70.19	87	69	92	70.19	60	61.7
116	68	77	68	110	68	41	69.23	59	69.23	87	68	91	69.23	58	60.5
116	67	77	67	106	67	40	68.27	58	68.27	83	67	90	68.27	58	59.3
114	66	77	66	105	66	40	67.31	58	67.31	82	66	87	67.31	56	58.0
112	65	74	65	105	65	38	66.35	57	66.35	82	65	86	66.35	55	56.8
112	64	74	64	100	64	37	65.38	55	65.38	81	64	85	65.38	53	55.6
111	63	74	63	100	63	36	64.42	53	64.42	80	63	85	64.42	53	54.3
111	62	73	62	97	62	36	63.46	53	63.46	80	62	84	63.46	52	53.1
110	61	73	61	96	61	35	62.50	52	62.50	78	61	84	62.50	51	51.9
109	60	73	60	96	60	34	61.54	52	61.54	75	60	84	61.54	51	50.6
108	59	73	59	94	59	34	60.58	50	60.58	75	59	83	60.58	46	49.4
107	58	72	58	94	58	33	59.62	50	59.62	74	58	82	59.62	46	48.1
103	57	72	57	94	57	32	58.65	50	58.65	73	57	81	58.65	43	46.9
102	56	72	56	90	56	31	57.69	48	57.69	71	56	78	57.69	43	45.7
101	55	69	55	90	55	30	56.73	48	56.73	70	55	78	56.73	43	44.4
98	54	68	54	90	54	29	55.77	47	55.77	70	54	76	55.77	42	43.2
96	53	68	53	90	53	29	54.81	47	54.81	68	53	75	54.81	41	42.0
95	52	68	52	90	52	28	53.85	46	53.85	67	52	73	53.85	41	40.7
95	51	68	51	87	51	28	52.88	46	52.88	67	51	73	52.88	41	39.5
94	50	68	50	86	50	28	51.92	44	51.92	66	50	71	51.92	40	38.3
94	49	67	49	85	49	27	50.96	43	50.96	65	49	68	50.96	38	37.0
93	48	66	48	84	48	27	50.00	43	50.00	64	48	67	50.00	36	35.8
91	47	66	47	82	47	27	49.04	43	49.04	63	47	65	49.04	35	34.6
90	46	66	46	81	46	23	48.08	43	48.08	62	46	62	48.08	33	33.3
88	45	66	45	77	45	22	47.12	43	47.12	62	45	62	47.12	32	32.1
88	44	65	44	76	44	20	46.15	42	46.15	61	44	61	46.15	32	30.9
88	43	59	43	74	43	20	45.19	42	45.19	59	43	61	45.19	30	29.6
87	42	59	42	72	42	19	44.23	42	44.23	59	42	59	44.23	30	28.4
87	41	57	41	71	41	18	43.27	40	43.27	59	41	57	43.27	26	27.2
87	40	57	40	70	40	18	42.31	40	42.31	58	40	57	42.31	22	25.9
86	39	57	39	70	39	17	41.35	38	41.35	58	39	56	41.35	17	24.7
85	38	55	38	66	38	17	40.38	38	40.38	58	38	55	40.38	17	23.5
82	37	53	37	66	37	16	39.42	38	39.42	58	37	54	39.42	16	22.2
81	36	53	36	65	36	16	38.46	37	38.46	57	36	53	38.46	16	21.0
81	35	51	35	64	35	15	37.50	37	37.50	57	35	53	37.50	15	19.8
75	34	51	34	63	34	15	36.54	37	36.54	55	34	50	36.54	11	18.5
73	33	51	33	62	33	14	35.58	36	35.58	55	33	48	35.58	11	17.3
71	32	51	32	60	32	13	34.62	36	34.62	54	32	46	34.62	10	16.0
69	31	51	31	60	31	12	33.65	35	33.65	54	31	45	33.65	7	14.8
67	30	50	30	59	30	12	32.69	34	32.69	53	30	44	32.69	6	13.6
67	29	50	29	56	29	12	31.73	34	31.73	53	29	44	31.73	6	12.3
66	28	50	28	55	28	12	30.77	34	30.77	51	28	41	30.77	6	11.1
65	27	49	27	55	27	11	29.81	33	29.81	51	27	41	29.81	5	9.9
59	26	48	26	55	26	11	28.85	32	28.85	51	26	40	28.85	5	8.6
56	25	48	25	55	25	11	27.88	32	27.88	50	25	39	27.88	4	7.4
56	24	48	24	54	24	11	26.92	30	26.92	50	24	38	26.92	4	6.2
54	23	47	23	54	23	10	25.96	30	25.96	48	23	31	25.96	4	4.9
53	22	47	22	54	22	10	25.00	30	25.00	47	22	30	25.00	2	3.7
53	21	47	21	53	21	9	24.04	29	24.04	46	21	30	24.04	2	2.5
50	20	46	20	52	20	9	23.08	28	23.08	46	20	29	23.08	1	1.2
49	19	46	19	50	19	9	22.12	27	22.12	46	19	29	22.12		
48	18	46	18	47	18	9	21.15	26	21.15	44	18	28	21.15		
48	17	44	17	44	17	8	20.19	23	20.19	44	17	26	20.19		
47	16	44	16	44	16	6	19.23	23	19.23	43	16	26	19.23		
43	15	43	15	43	15	5	18.27	23	18.27	42	15	25	18.27		
42	14	43	14	40	14	4	17.31	22	17.31	41	14	23	17.31		
42	13	42	13	37	13	4	16.35	22	16.35	41	13	23	16.35		
42	12	40	12	34	12	4	15.38	18	15.38	39	12	23	15.38		
39	11	40	11	30	11	4	14.42	17	14.42	37	11	23	14.42		
38	10	38	10	30	10	3	13.46	17	13.46	36	10	21	13.46		
38	9	37	9	30	9	3	12.50	17	12.50	35	9	20	12.50		
37	8	36	8	26	8	3	11.54	16	11.54	34	8	19	11.54		
36	7	35	7	26	7	3	10.58	15	10.58	33	7	18	10.58		
36	6	34	6	22	6	3	9.62	11	9.62	30	6	17	9.62		
34	5	32	5	17	5	3	8.65	10	8.65	30	5	14	8.65		
32	4	29	4	10	4	3	7.69	9	7.69	30	4	13	7.69		
29	3	26	3	8	3	3	6.73	7	6.73	29	3	11	6.73		
26	2	23	2	5	2	3	5.77	7	5.77	26	2	10	5.77		
21	1	18	1	3	1	3	4.81	4	4.81	24	1	6	4.81		
						3	3.85	3	3.85			6	3.85		
						3	2.88	3	2.88			4	2.88		
						3	1.92	3	1.92			4	1.92		
						3	0.96	3	0.96			3	0.96		
	94		68		86		27		43		66		67		49
	170		93		150		62		74		110		124		100

WF Buckhorn Cr (mm)	% finer					
1050	100					
1050	99					
1050	98					
1000	97					
1000	96					
1000	95					
1000	94					
900	93					
750	92					
750	91					
750	90					
600	89					
600	88					
530	87					
530	86					
530	85					
510	84					
510	83					
390	82					
390	81					
390	80					
380	79					
380	78					
350	77					
325	76					
325	75					
320	74					
320	73					
320	72					
320	71					
300	70					
300	69					
300	68					
300	67					
300	66					
300	65					
280	64					
270	63					
270	62					
270	61					
250	60					
250	59					
240	58					
240	57					
232	56					
230	55					
230	54					
220	53					
190	52					
190	51					
180	50					
170	49					
170	48					
160	47					
140	46					
130	45					
125	44					
123	43					
120	42					
110	41					
105	40					
102	39					
100	38					
90	37					
90	36					
90	35					
90	34					
83	33					
80	32					
75	31					
71	30					
70	29					
65	28					
65	27					
65	26					
52	25					
50	24					
50	23					
45	22					
40	21					
30	20					
30	19					
15	18					
13	17					
12	16					
11	15					
3	14					
3	13					
3	12					
3	11					
3	10					
3	9					
3	8					
3	7					
3	6					
3	5					
3	4					
3	3					
3	2					
3	1					
	180					
	510					

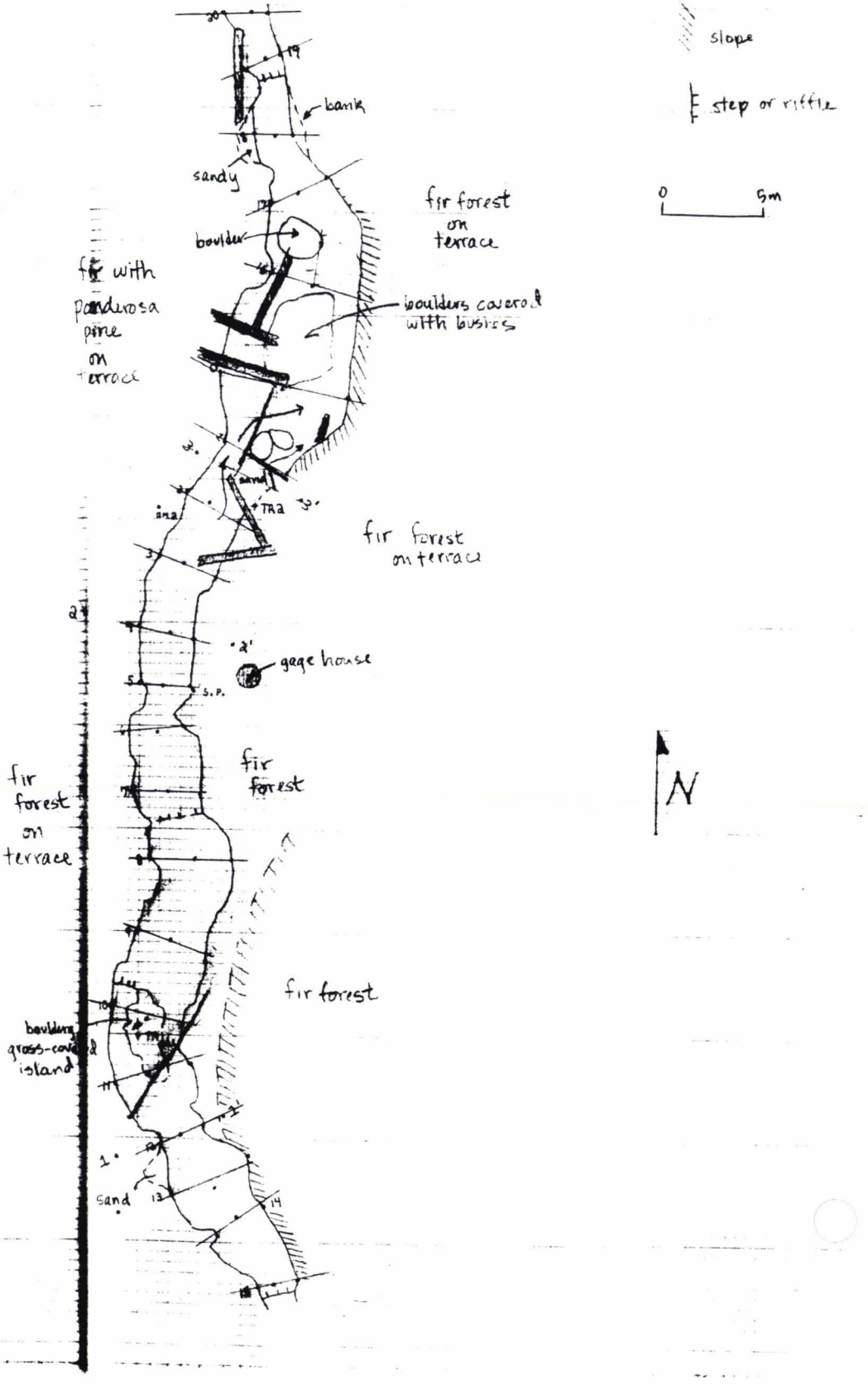
Appendix B -

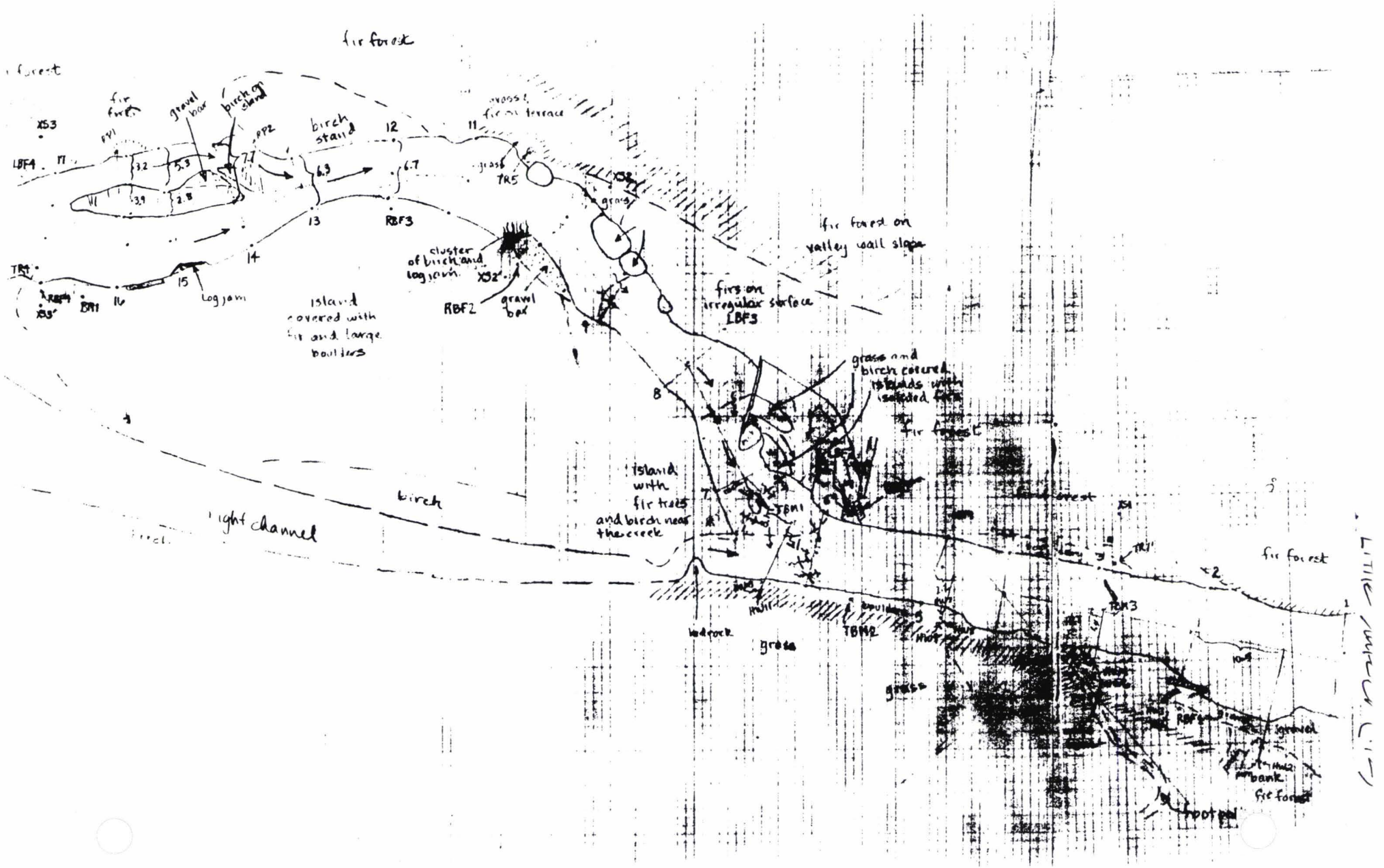
The bedload rating curves

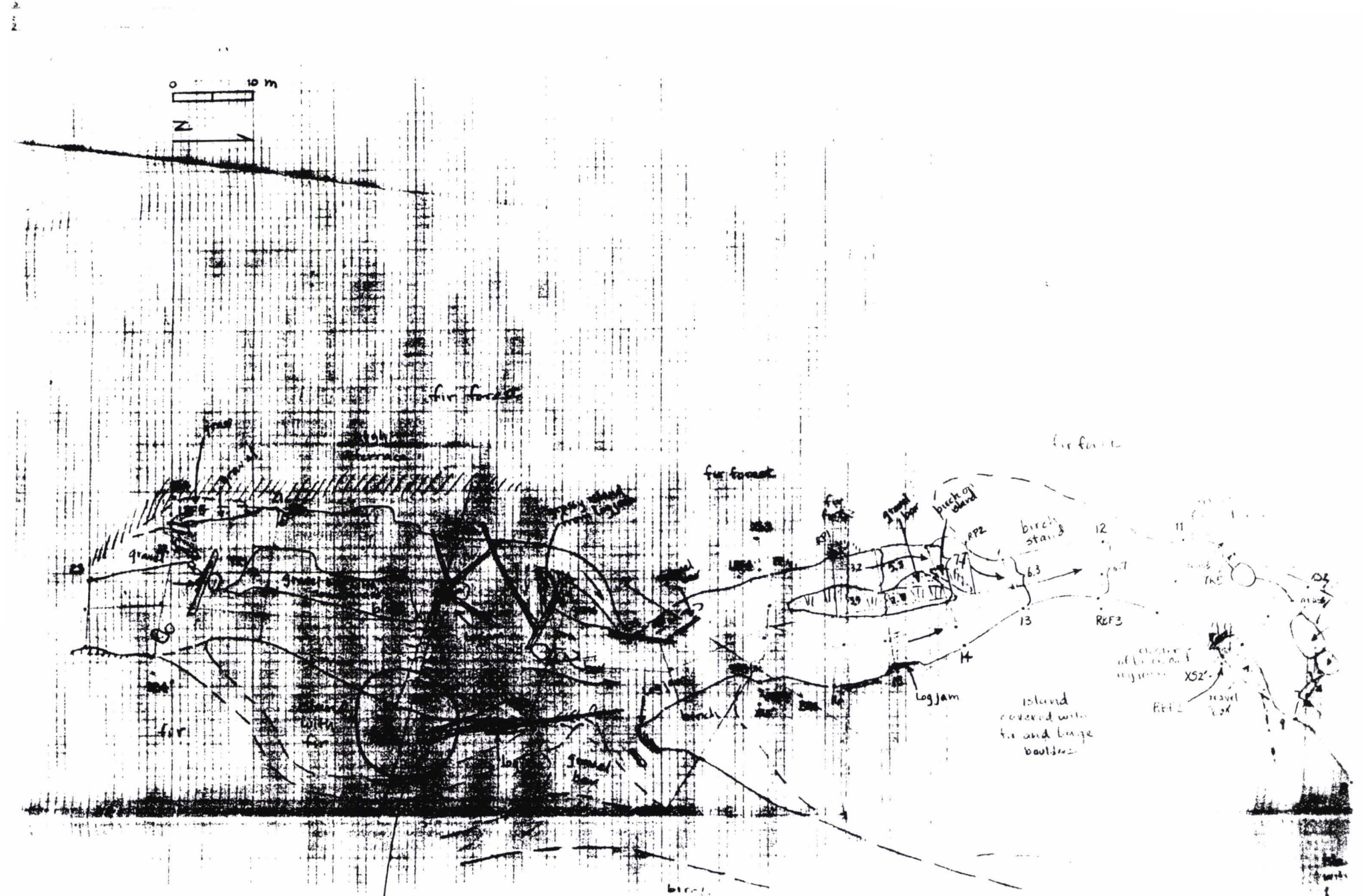
LITTLE BUCKHORN CR

LITTLE BUCKHORN CREEK

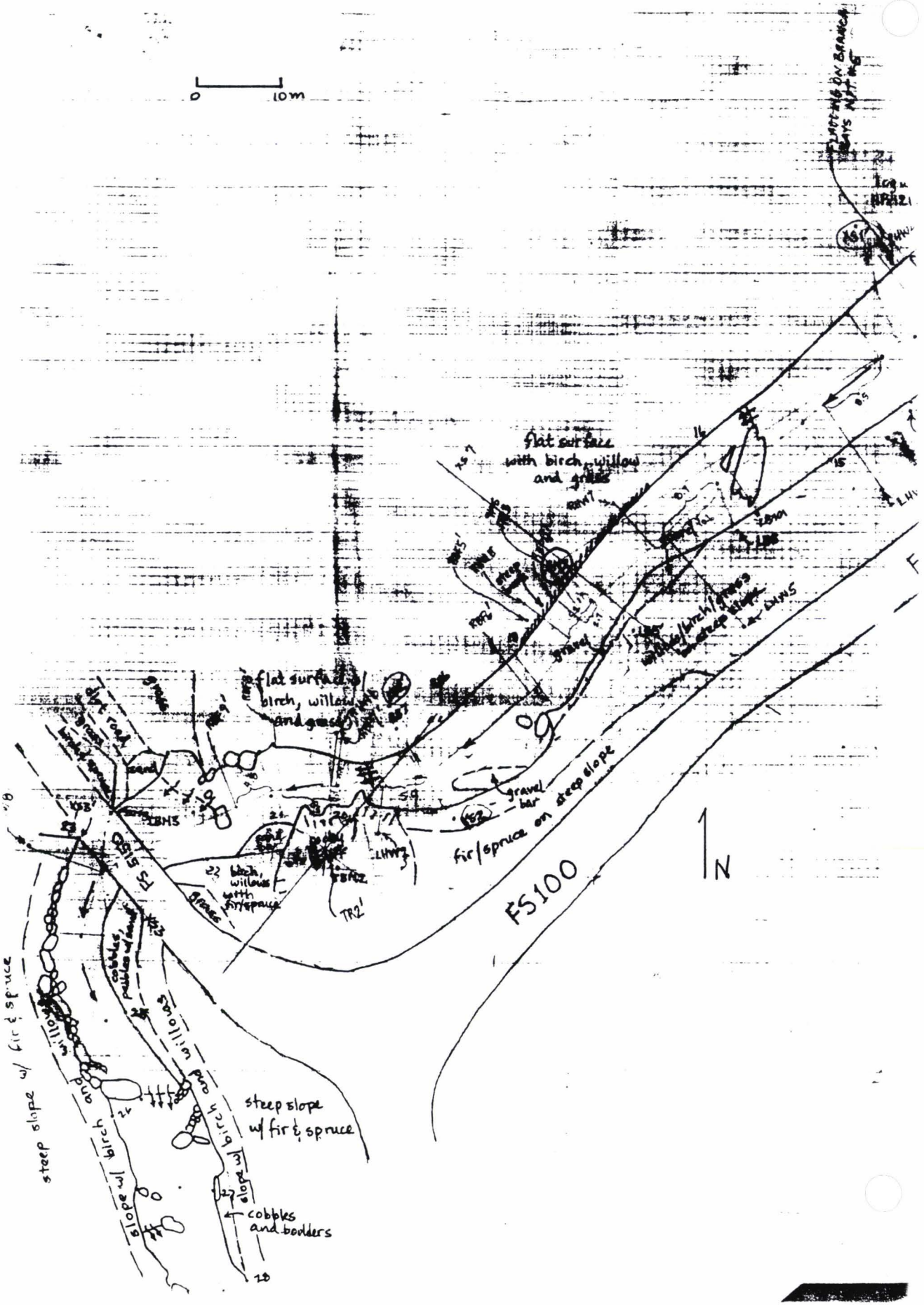
PAYETTE NATIONAL FOREST



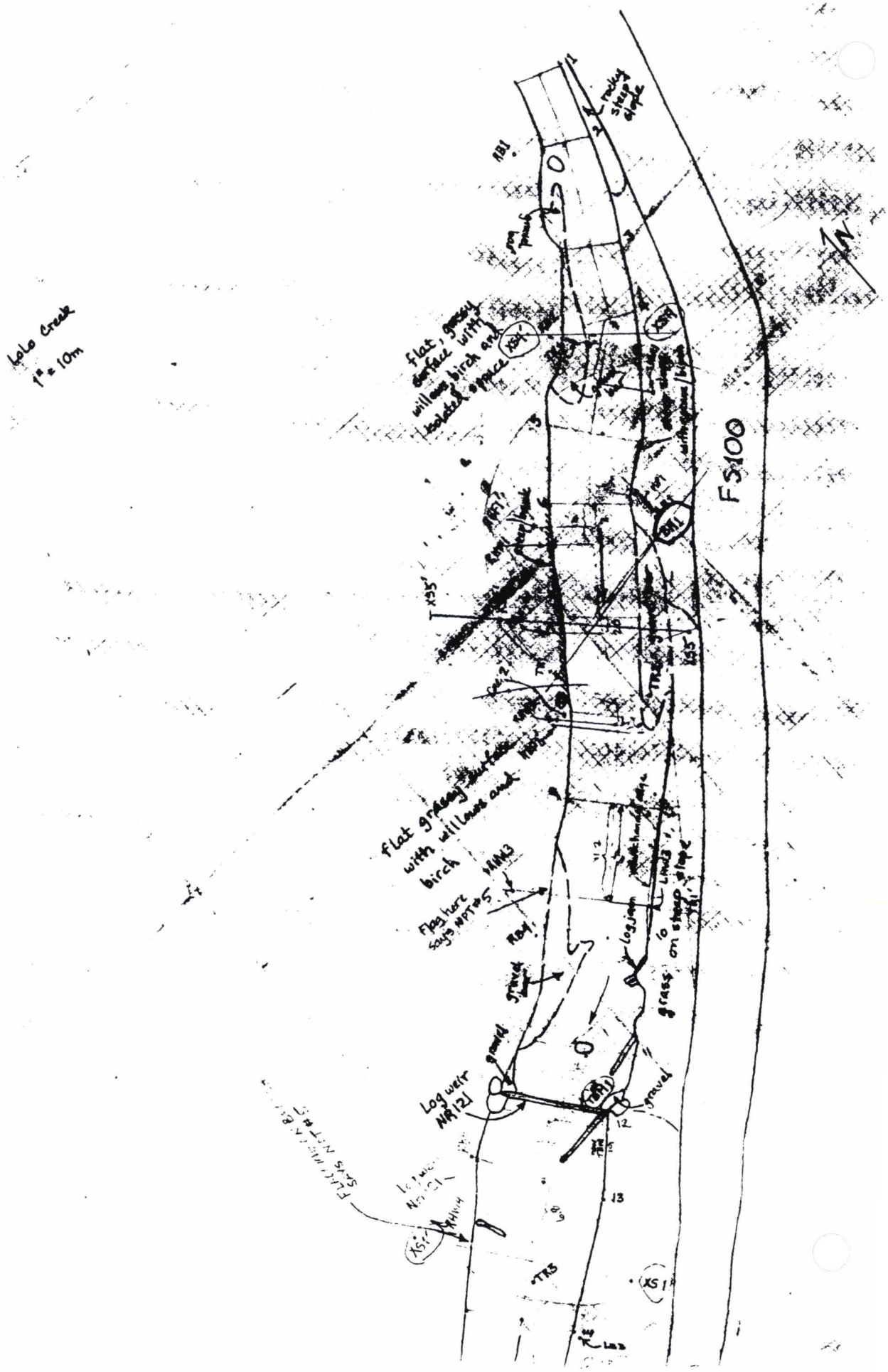

fir forest
fir forest
gravel bar
birch on island
XS3
PP1
PP2
birch stand
12
11
grass, fir on terrace
LBF4
11
3.2
5.3
7.7
6.9
6.7
3.9
2.8
TR5
XS4
grass
13
RBF3
fir forest on valley wall slope
cluster of birch and logs on
14
XS2
TR4
15
Log jam
RBF2
gravel bar
XS5
BM1
16
island covered with fir and large boulders
fir on irregular surface LBF3
grass and birch covered islands with isolated fir
8
fir forest
island with fir trees and birch near the creek
TBM1
birch
light channel
fir forest
TR1
TBM3
TBM2
bedrock
grass
gravel
bank
fir forest
floodplain

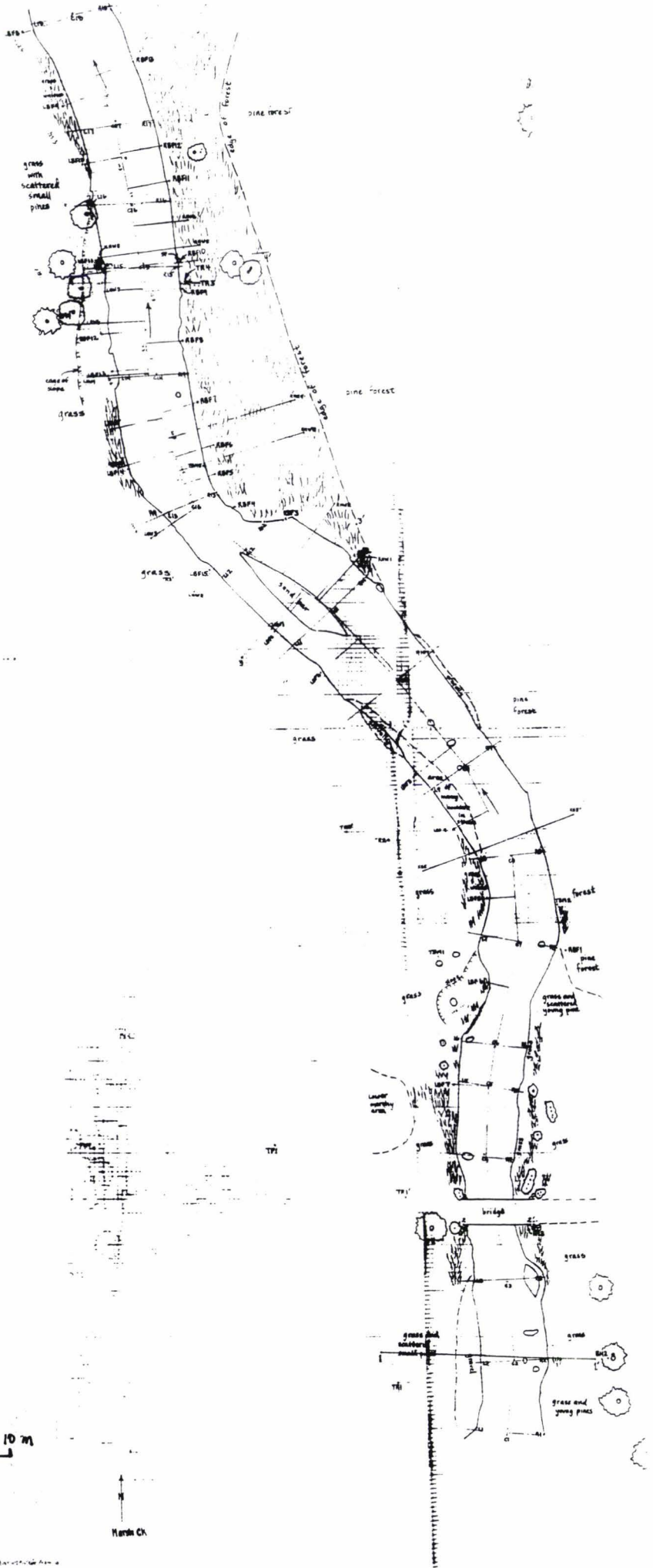

0 10 m
N
fir forest
fir forest
fir forest
gravel bar
gravel bar
birch stand
birch of island
PP2
12
11
13
REF3
6.3
3.2
5.3
3.9
Log Jam
island covered with fir and large boulders
XS2'
REF2
gravel bar
fir
Place RP in this area

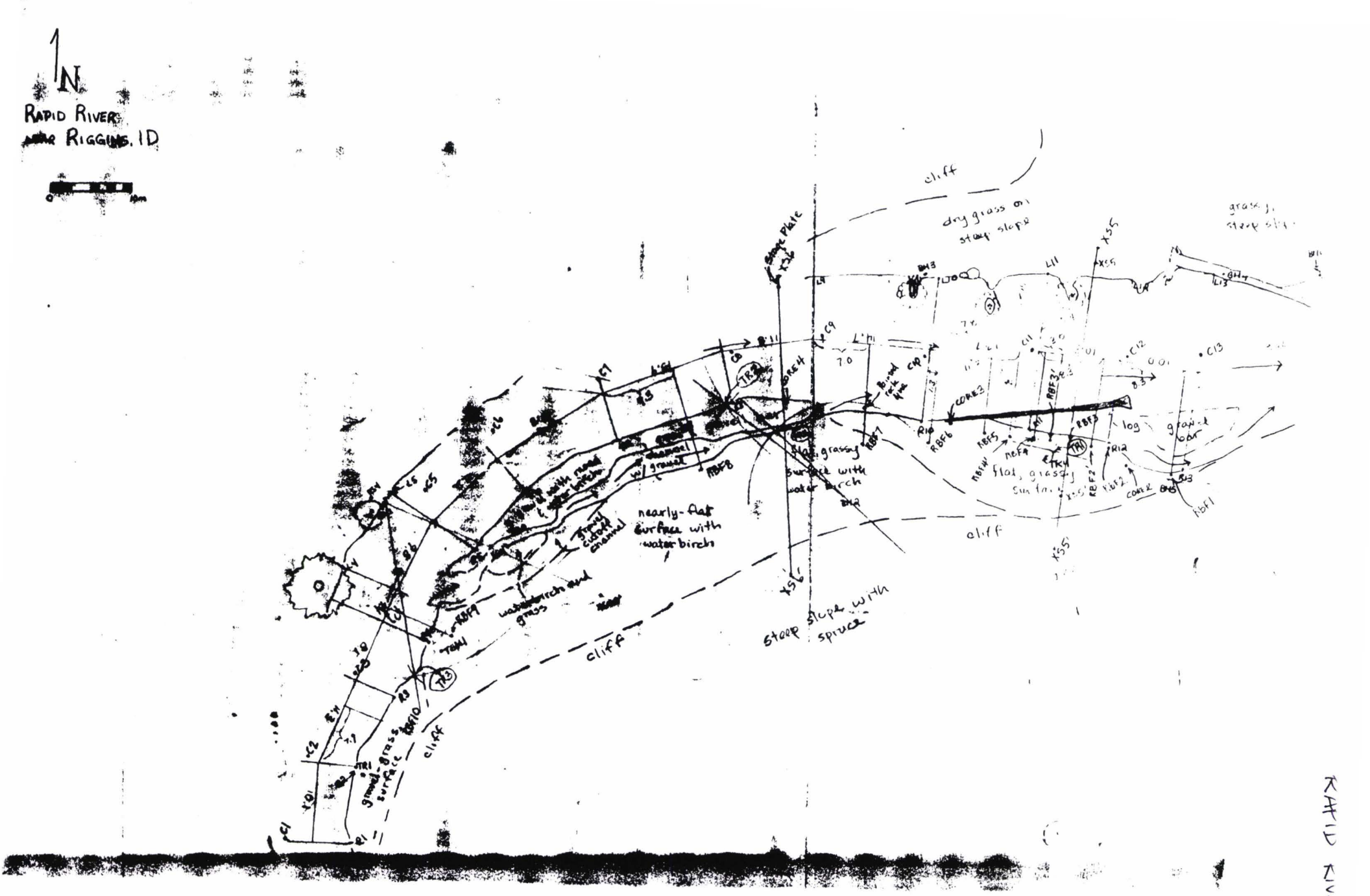
LOLO CREEK (1/2)

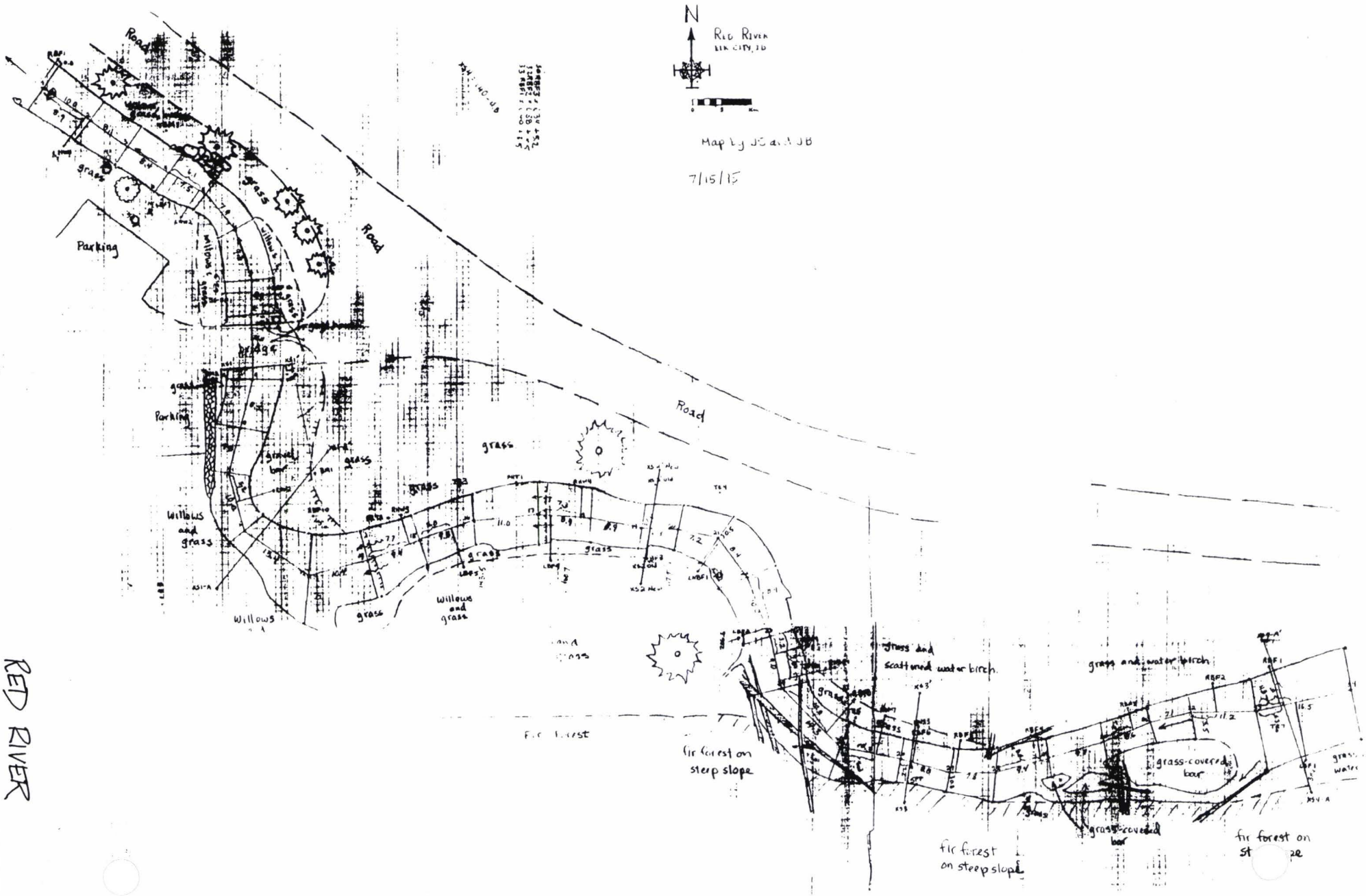


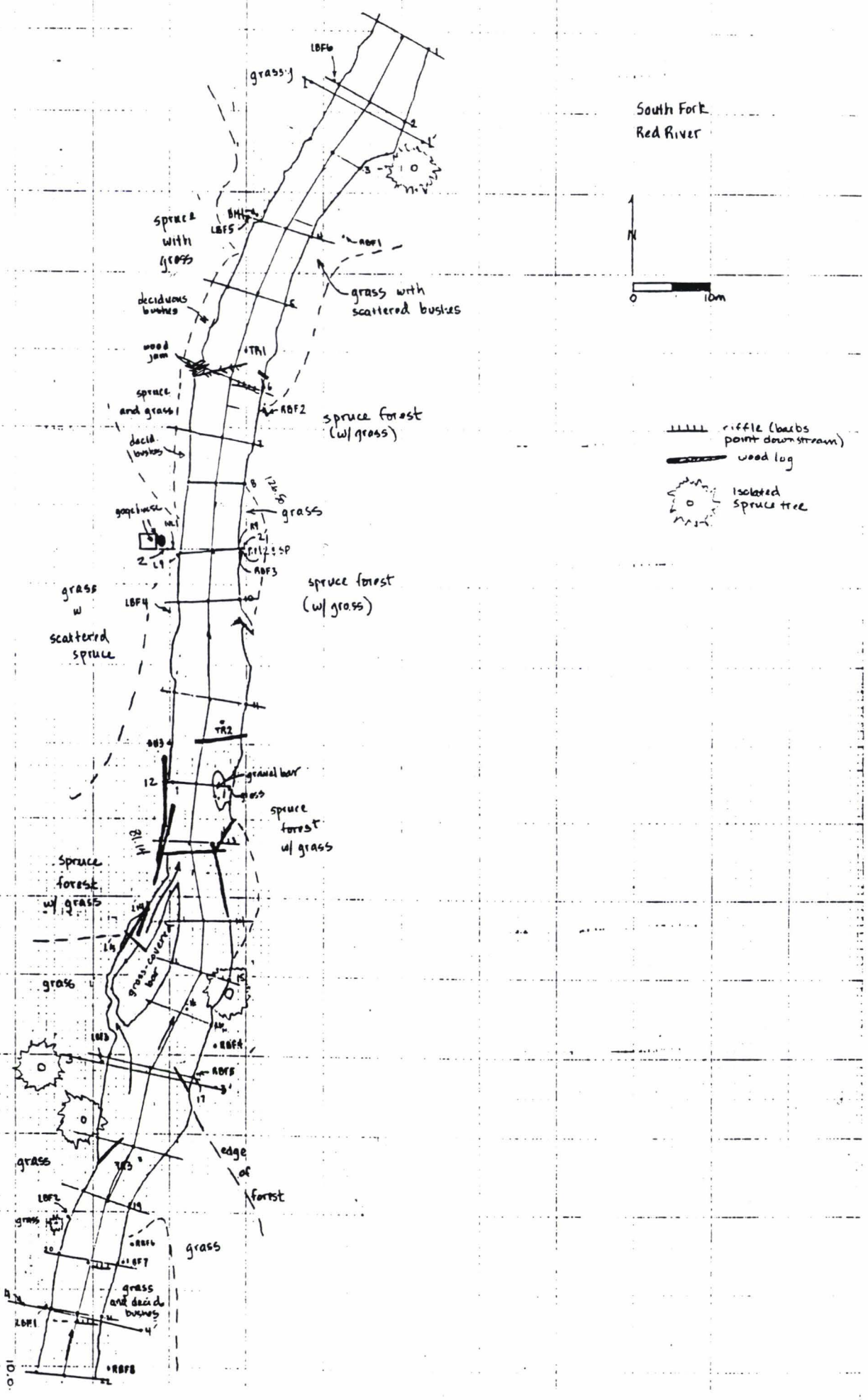
Lolo Creek (42)



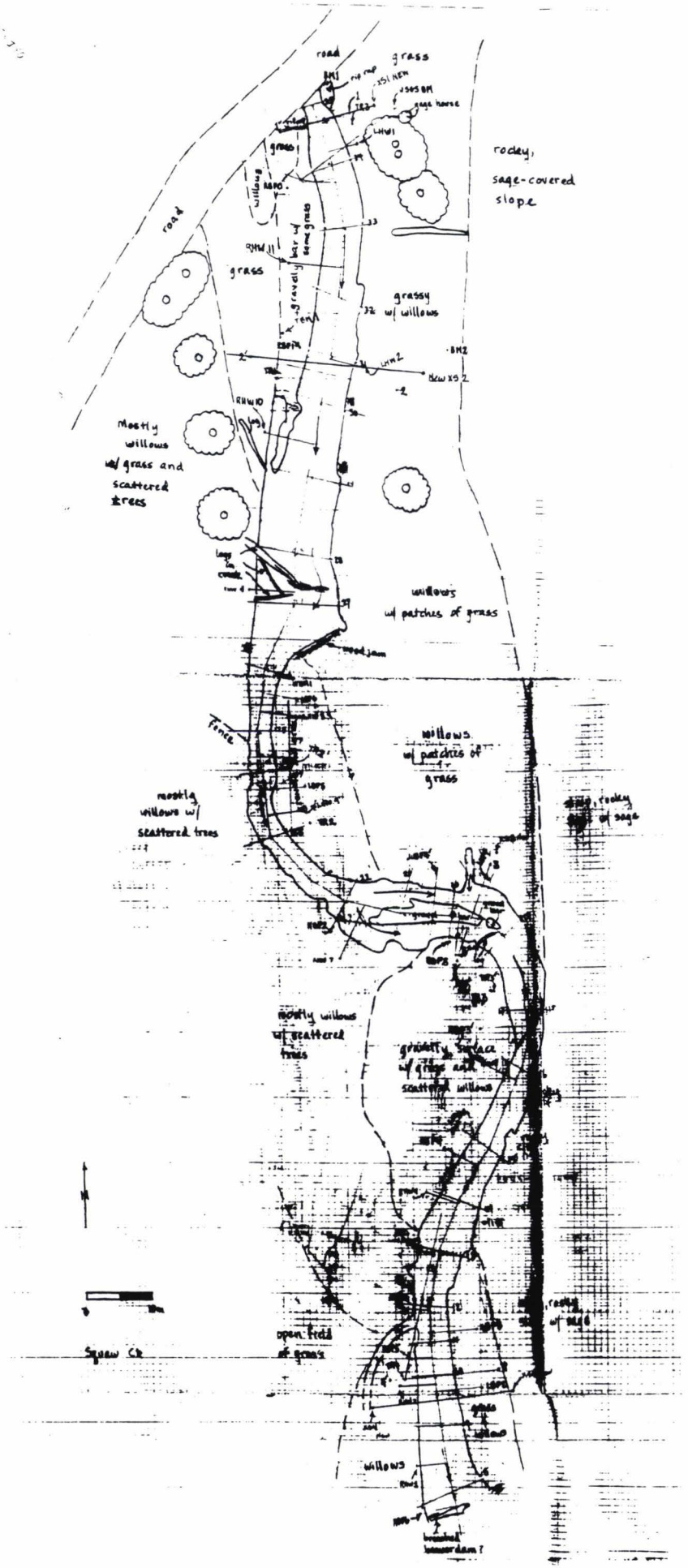

pine forest
grass with scattered small pines
grass
pine forest
grass
pine forest
grass
pine forest
grass and scattered young pine
grass
bridge
grass
grass and scattered young pine
grass and young pines
0 10 m
N
Marsh Ck


N
RAPID RIVER
NEAR RIGGINS, ID
cliff
dry grass on steep slope
steep slope with spruce
nearly-flat surface with water birch
cliff
cliff
flat, grassy surface with water birch
grassy, steep slope
log
gravel bar
RAPID RIVER

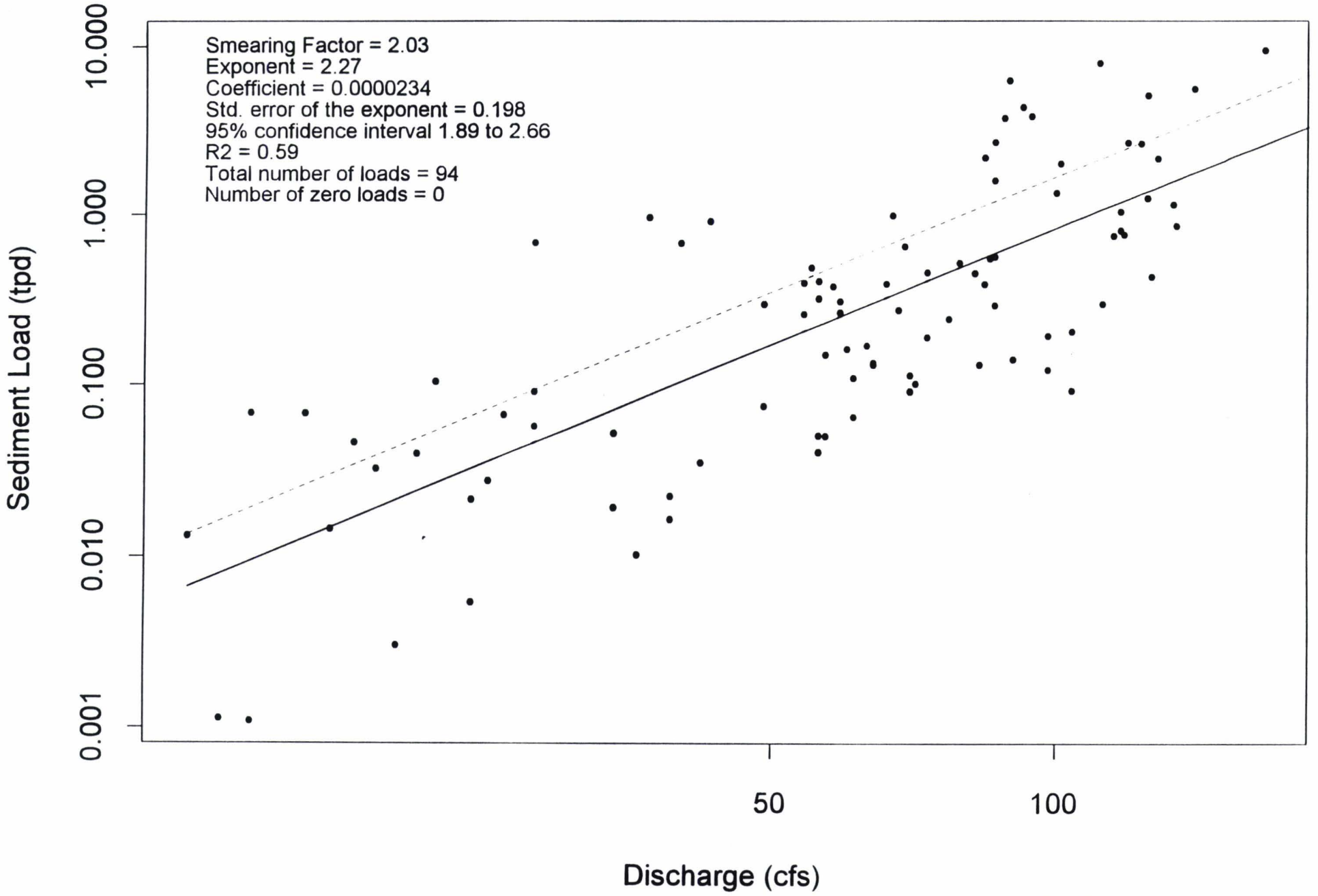

N
Red River
Elk City, ID
Map by JS and JB
7/15/15
Road
Road
Road
Parking
Parking
grass
grass
grass
grass
grass
grass
grass
grass
Willows and grass
Willows and grass
Willows and grass
grass and scattered water birch
grass and water birch
fir forest on steep slope
fir forest on steep slope
fir forest on steep slope
grass-covered bar
grass-covered bar
RBF1
RBF2
RBF3
RBF4
RBF5
RBF6
RED RIVER


South Fork
Red River
N
0
10m
riffle (barbs point downstream)
wood log
isolated spruce tree
grassy
LBF6
RBF1
spruce with grass
grass with scattered bushes
deciduous bushes
wood jam
TR1
RBF2
spruce and grass
spruce forest (w/ grass)
decid bushes
grass
gage house
RBF3
LBF4
grass w scattered spruce
spruce forest (w/ grass)
TR2
gravel bar
spruce forest w/ grass
spruce forest w/ grass
grass
grass-covered bar
RBF4
RBF5
edge of forest
grass
TR3
LBF7
grass
RBF6
grass and decid bushes
LBF1
RBF8

SQUAW CREEK

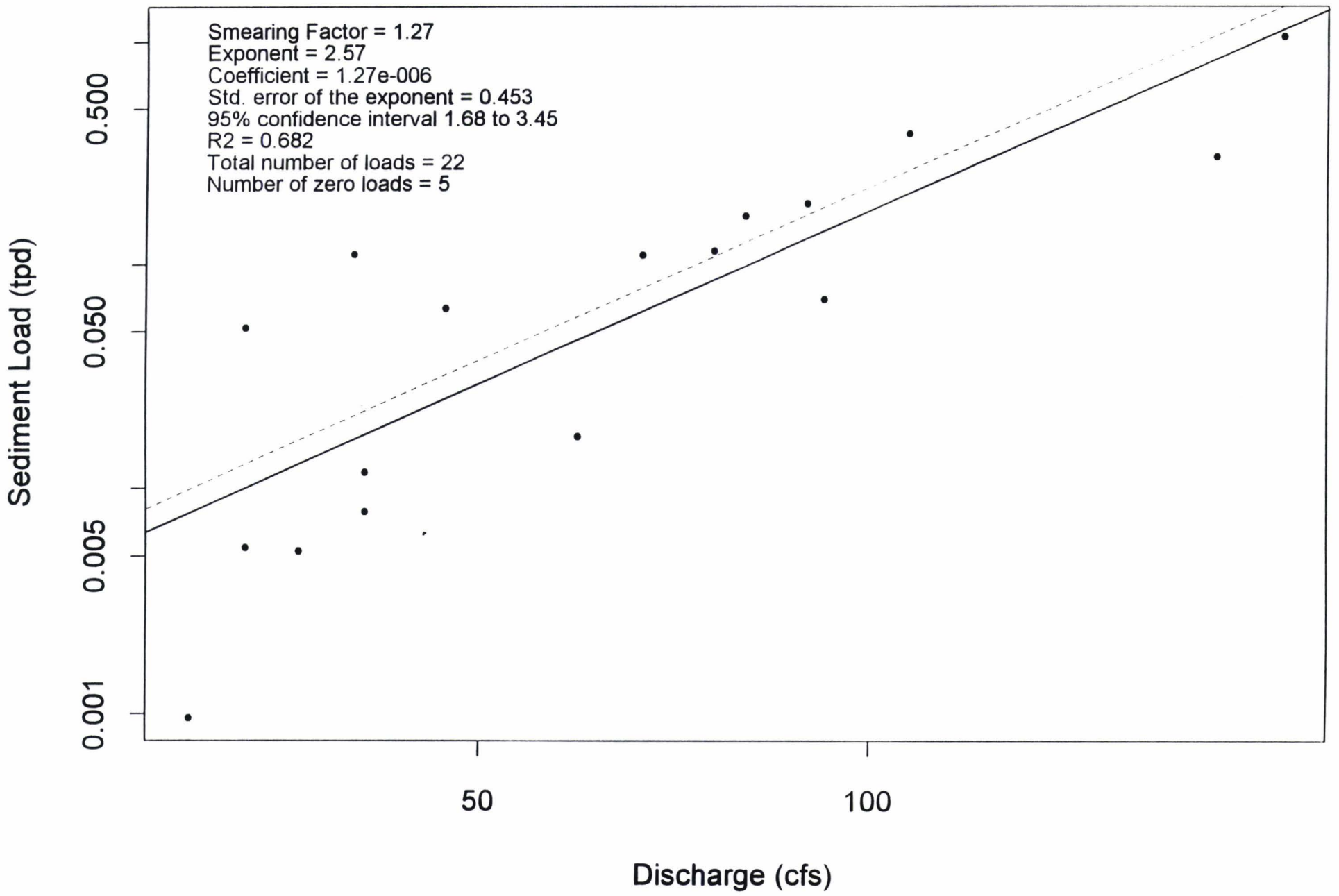

road
grass
rocky, sage-covered slope
road
willows
gravelly bar of young grass
grass
grassy w/ willows
mostly willows w/ grass and scattered trees
willows w/ patches of grass
fence
willows w/ patches of grass
mostly willows w/ scattered trees
mostly willows w/ scattered trees
grassy w/ patches of grass and scattered willows
Squaw Ck
open field of grass
willows

Blackmare Ck., Bedload > 0.85 mm



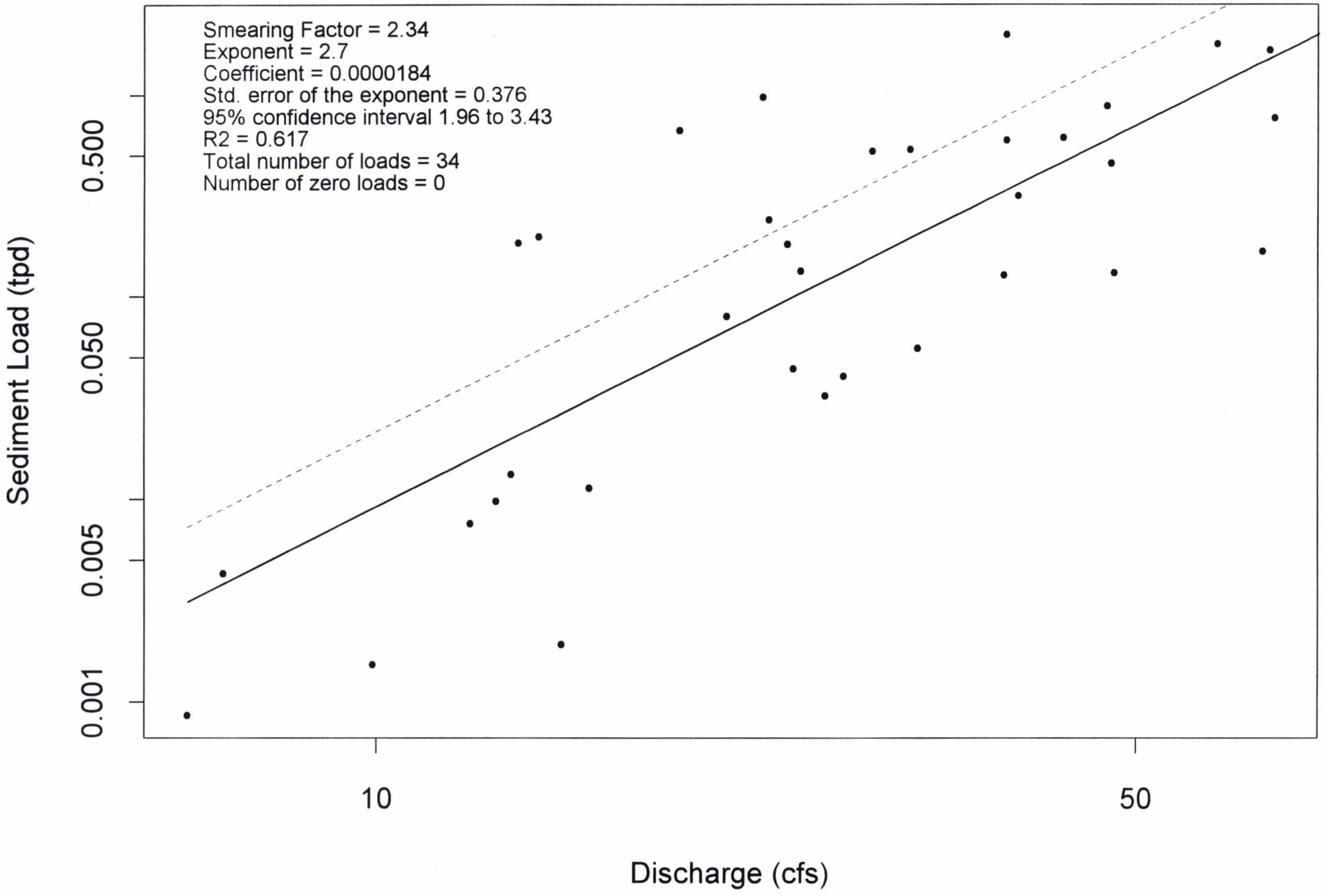
Fri Dec 6 13:52:26 1996

Canyon Ck., Bedload > 0.85 mm



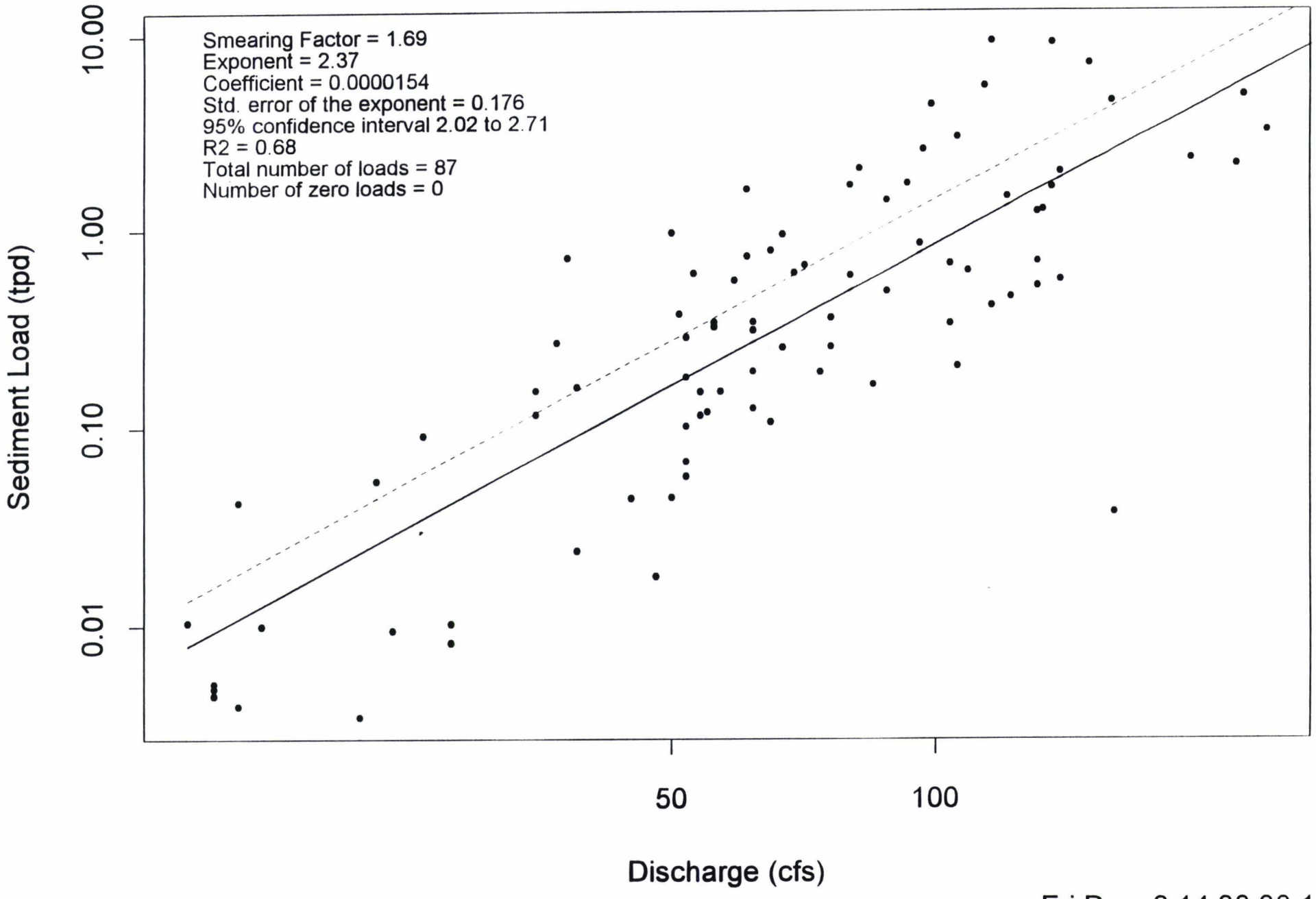
Fri Dec 6 14:29:50 1996

Catspur Ck., Bedload > 0.85 mm



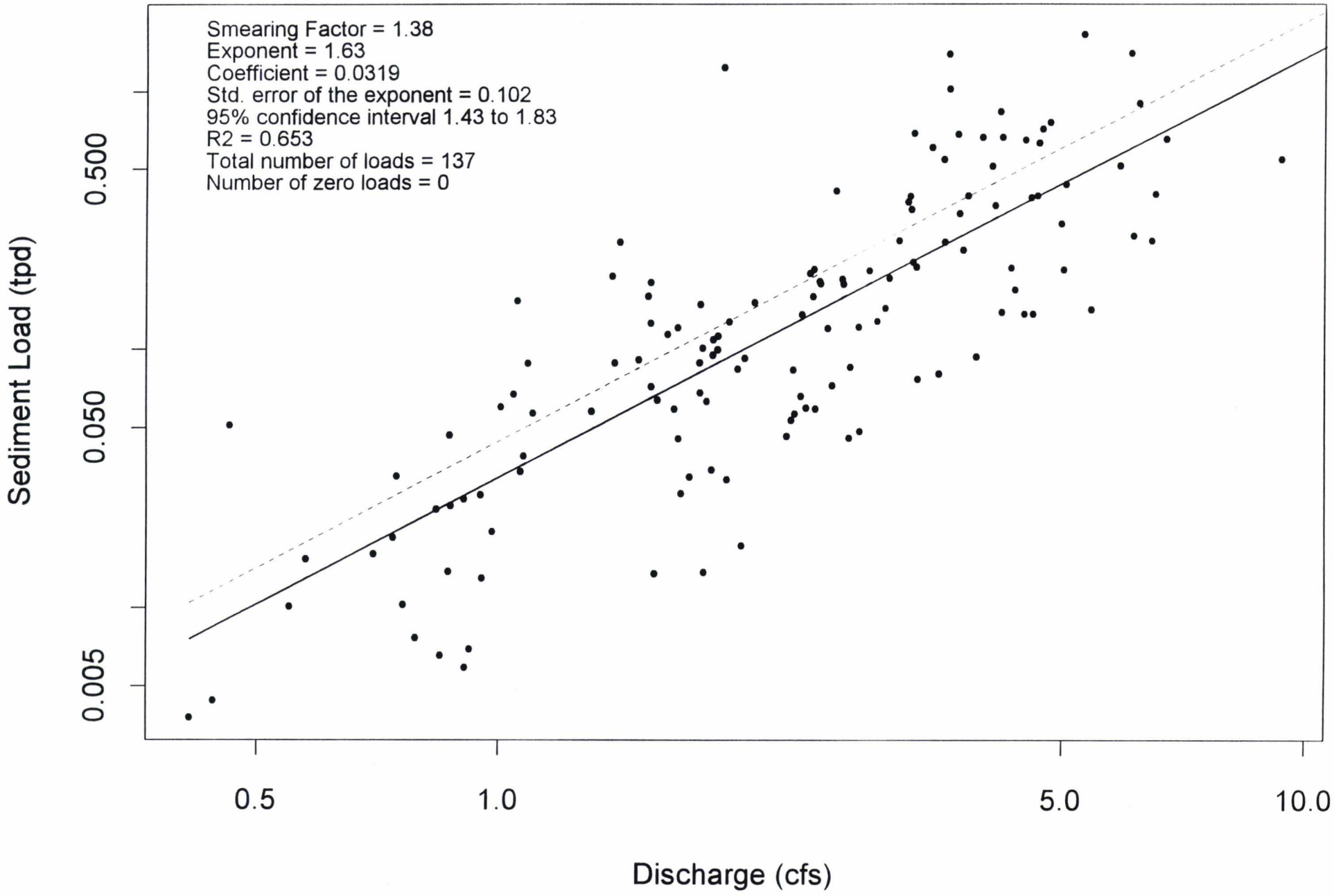
Tue Feb 4 11:17:50 1997

Dollar Ck., Bedload > 0.85 mm



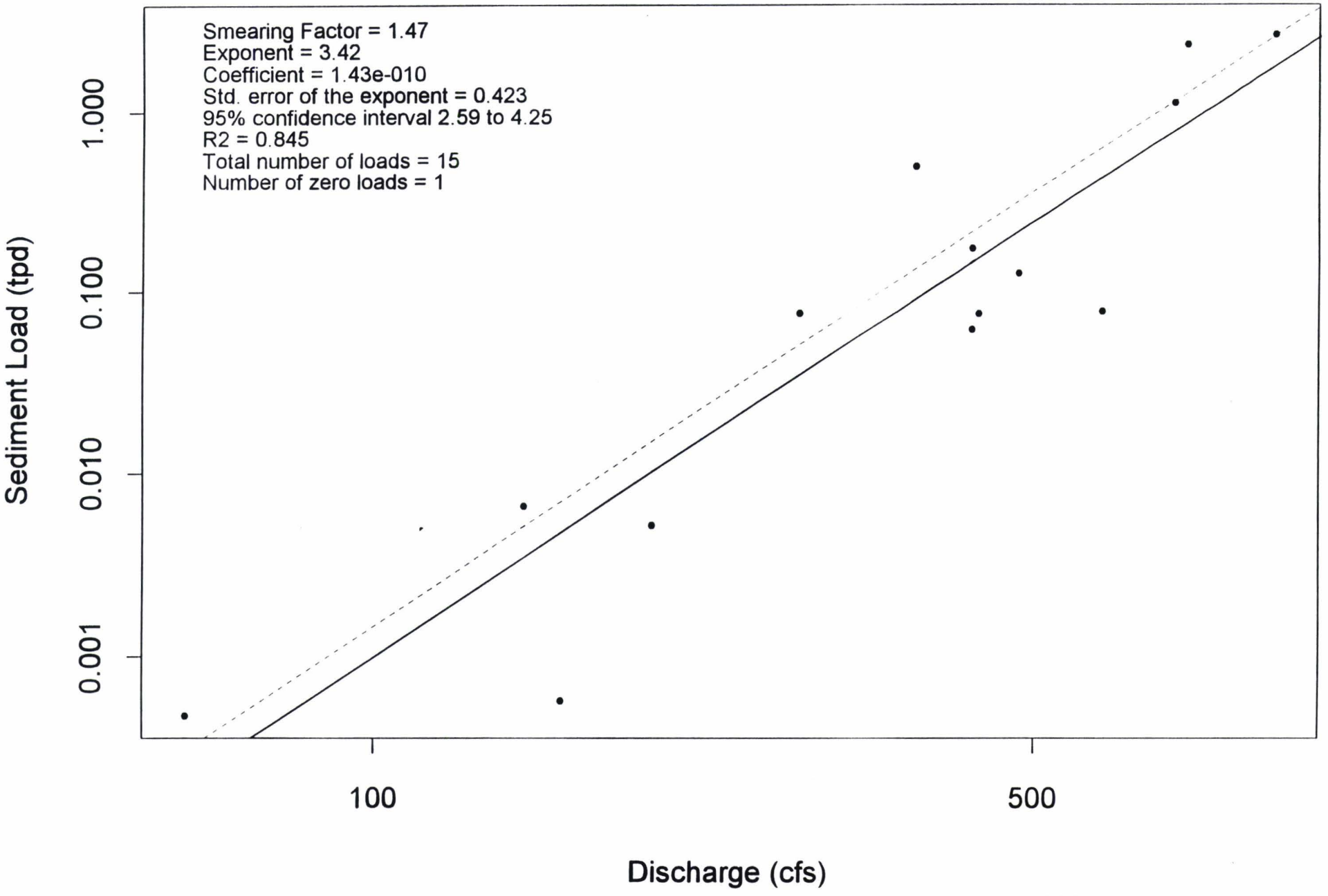
Fri Dec 6 14:38:38 1996

Eggers Ck. Bedload, All sizes



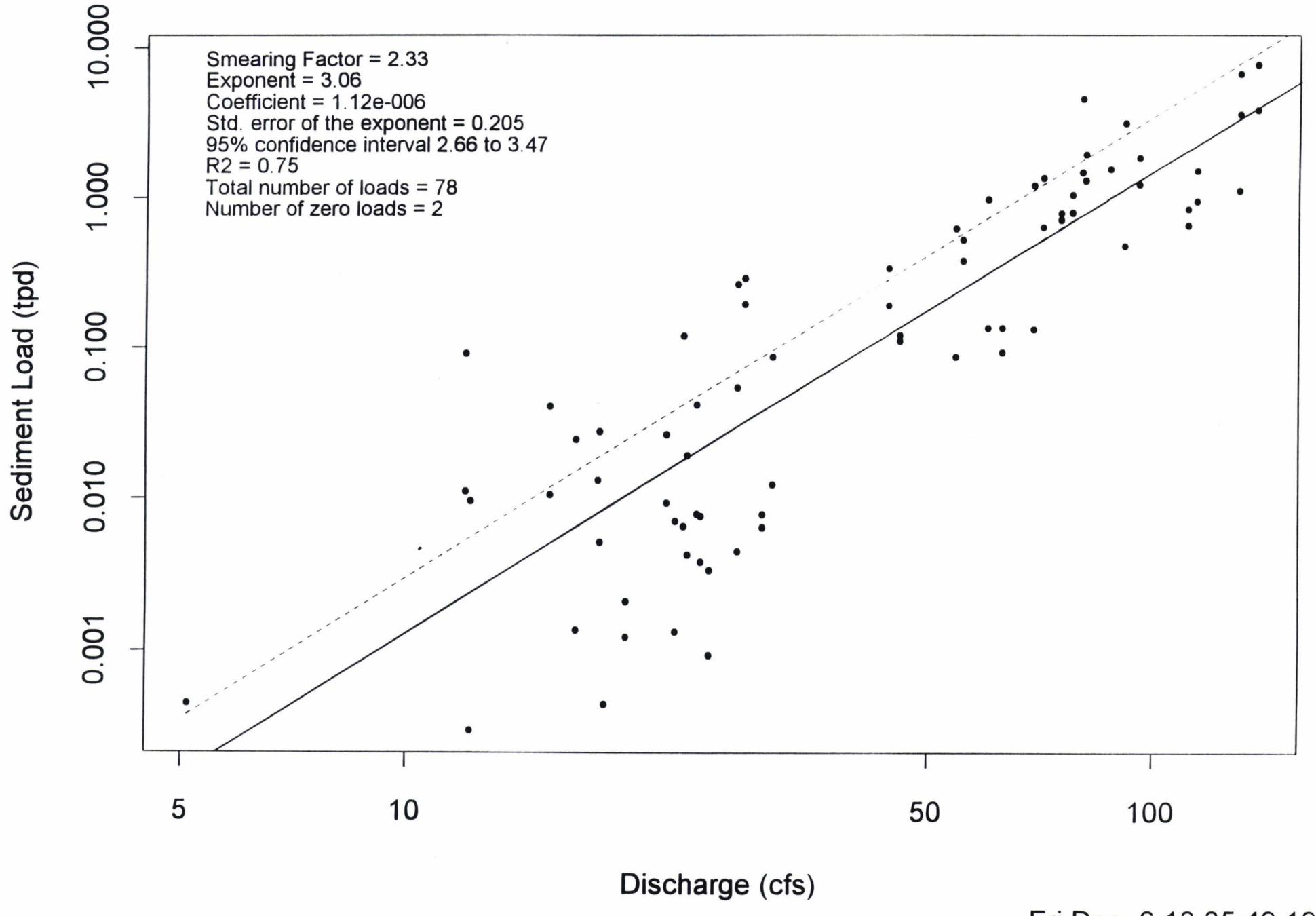
Thu Jan 9 16:22:34 1997

Fish Ck., Bedload > 0.85 mm



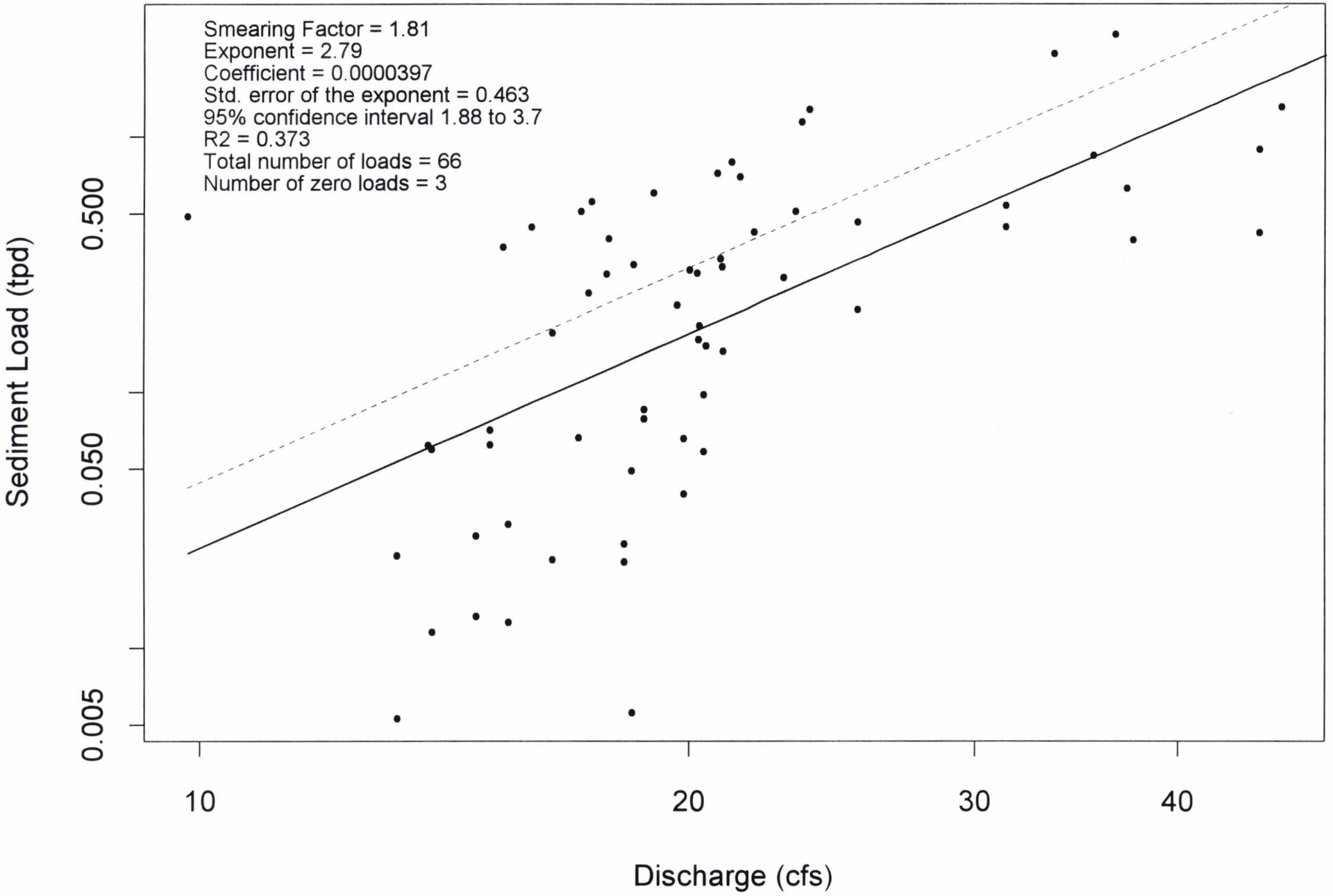
Fri Dec 6 15:11:56 1996

4th of July Ck., Bedload > 0.85 mm



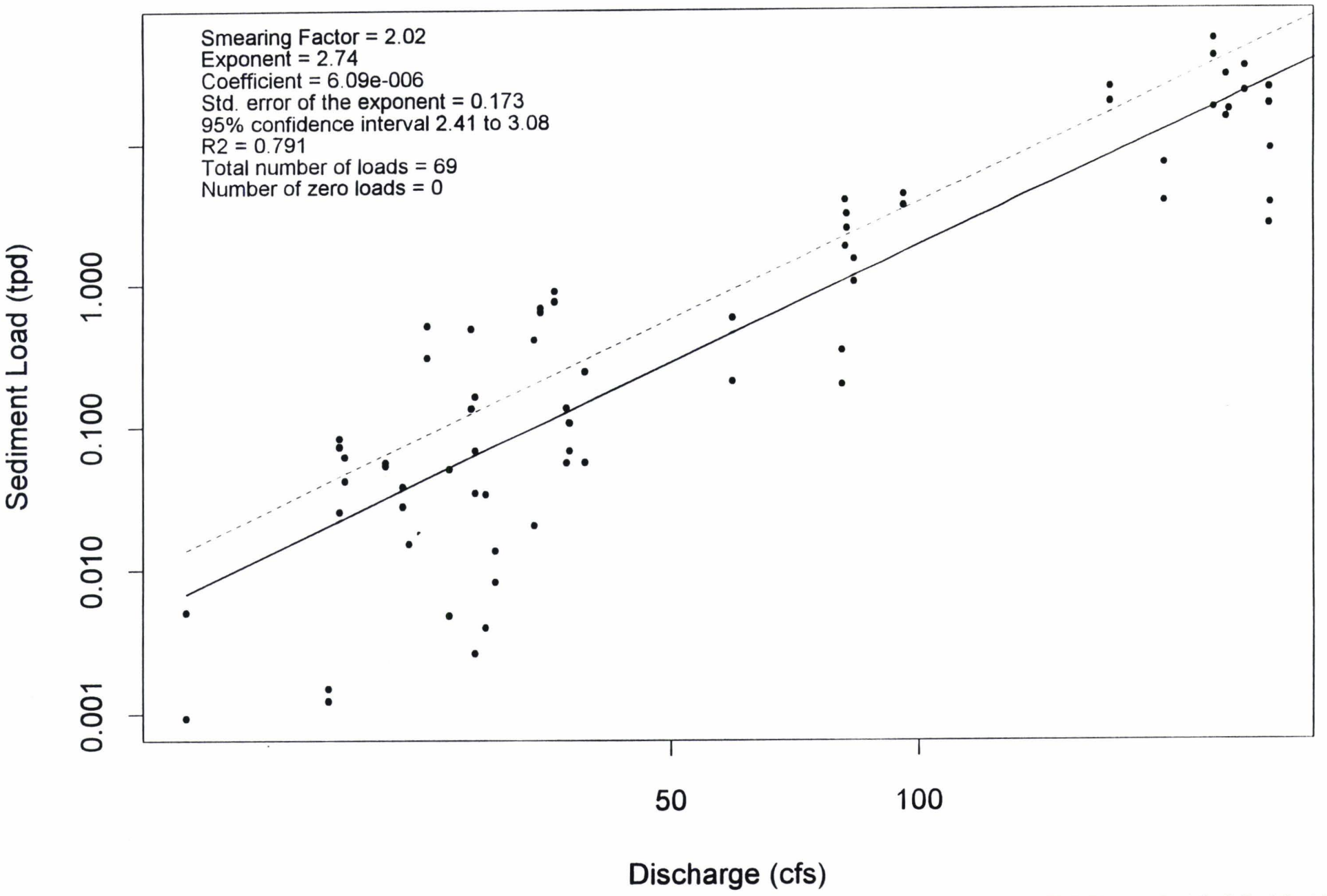
Fri Dec 6 13:35:49 1996

Hawley Ck. Bedload > 0.85 mm 1990-94



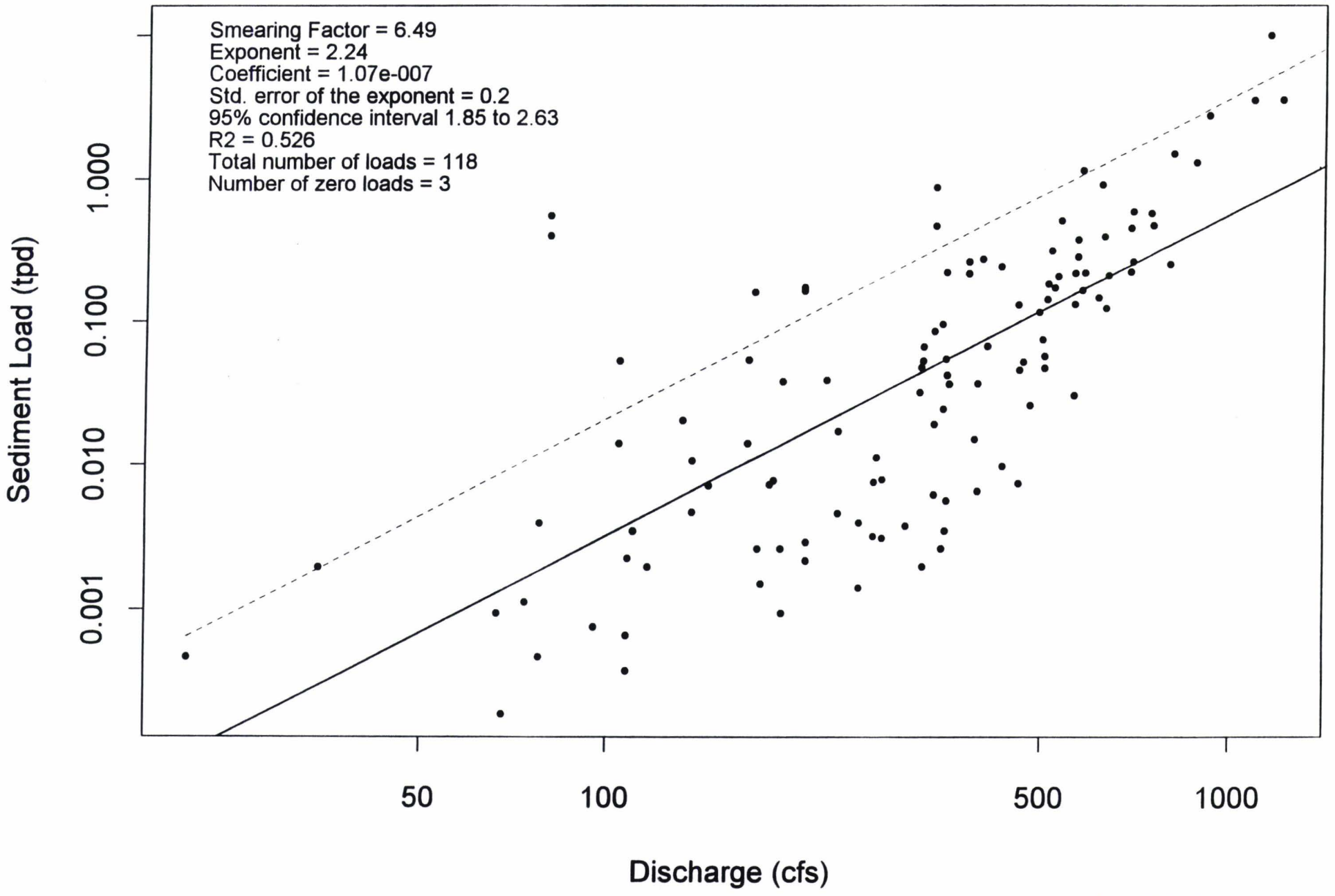
Fri Jan 10 16:02:05 1997

Herd Ck., Bedload > 0.85 mm



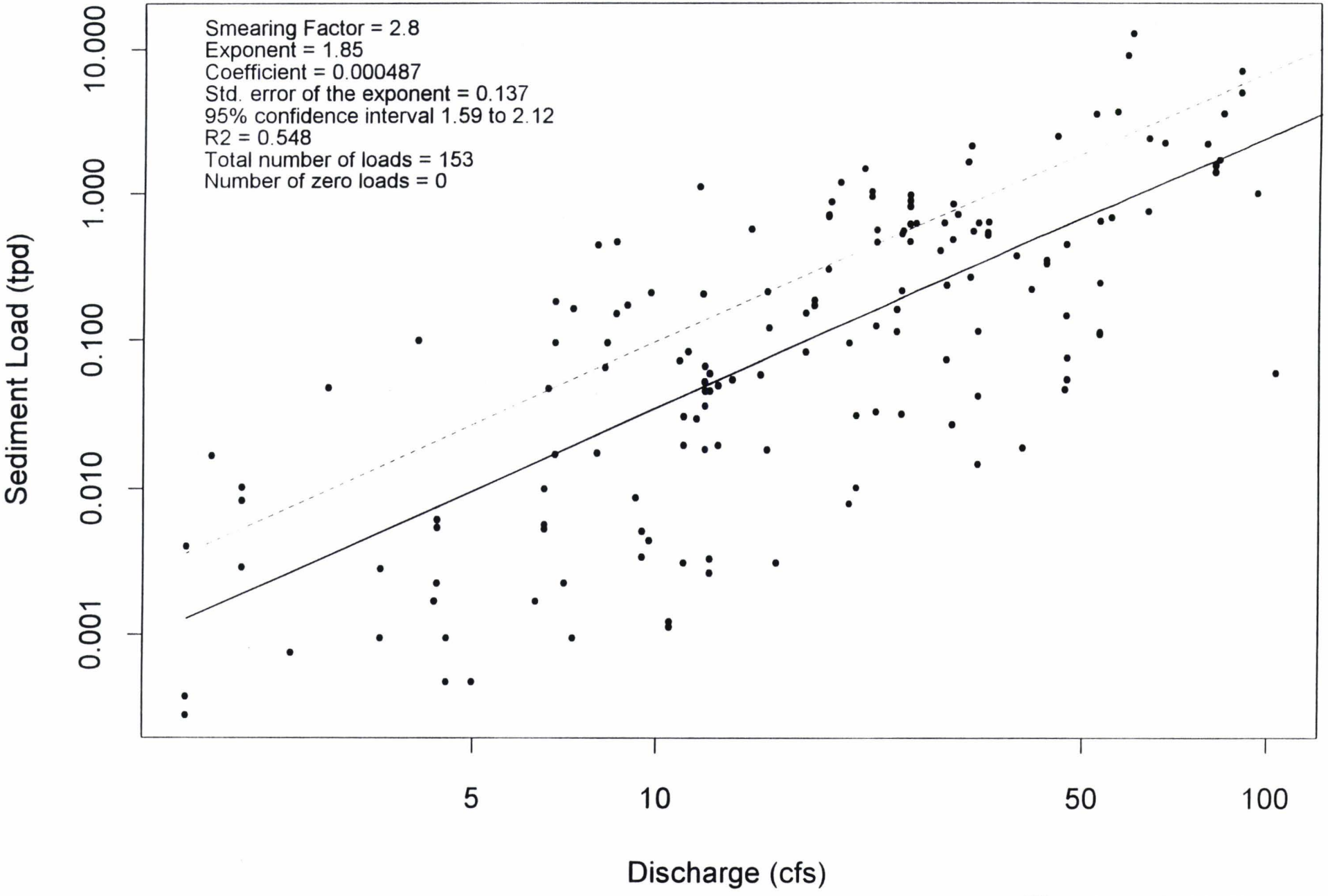
Fri Dec 6 13:36:49 1996

Johns Ck, Bedload > 0.85mm



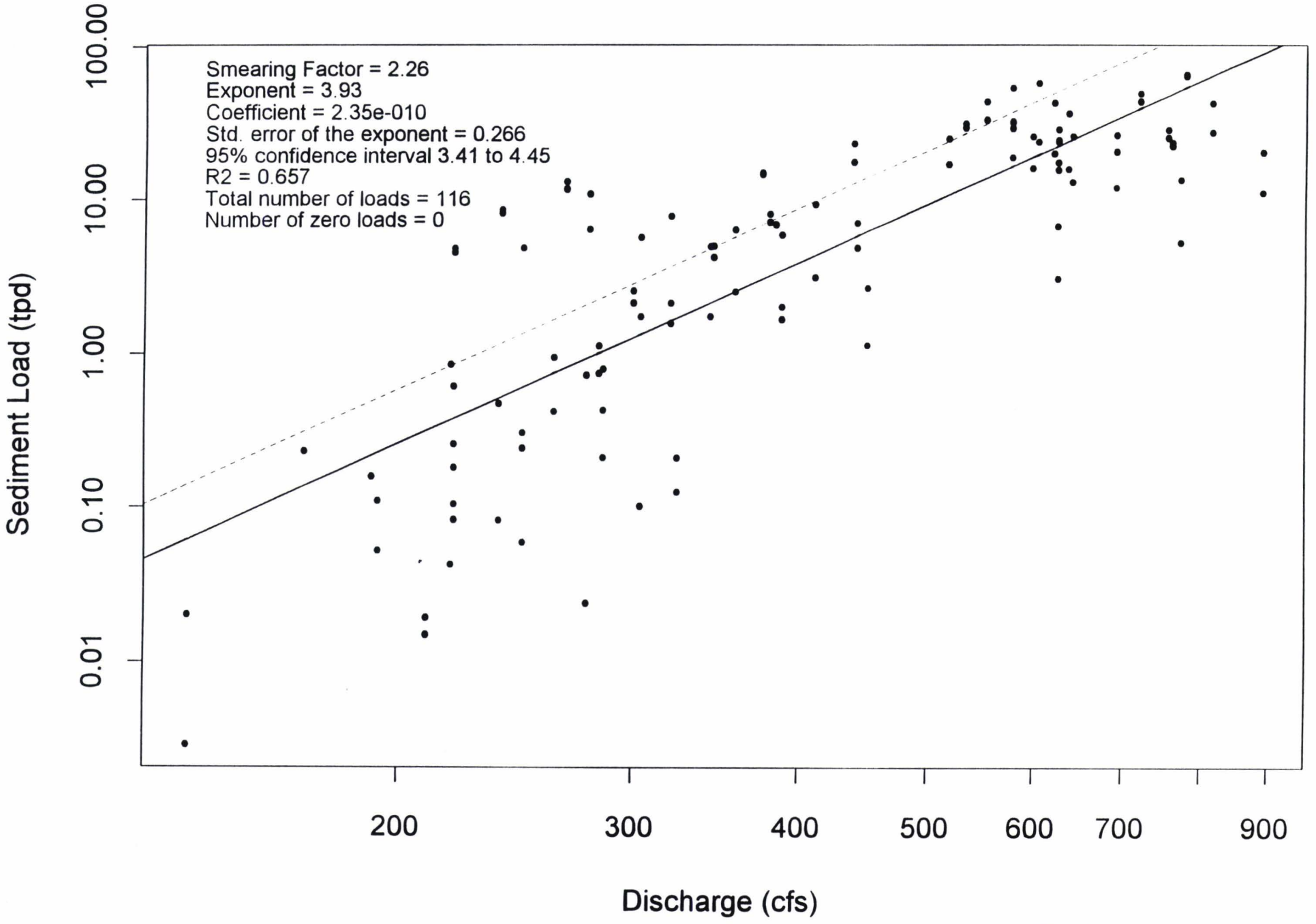
Wed Jan 22 21:48:32 1997

Trapper Ck., Bedload > 0.85 mm



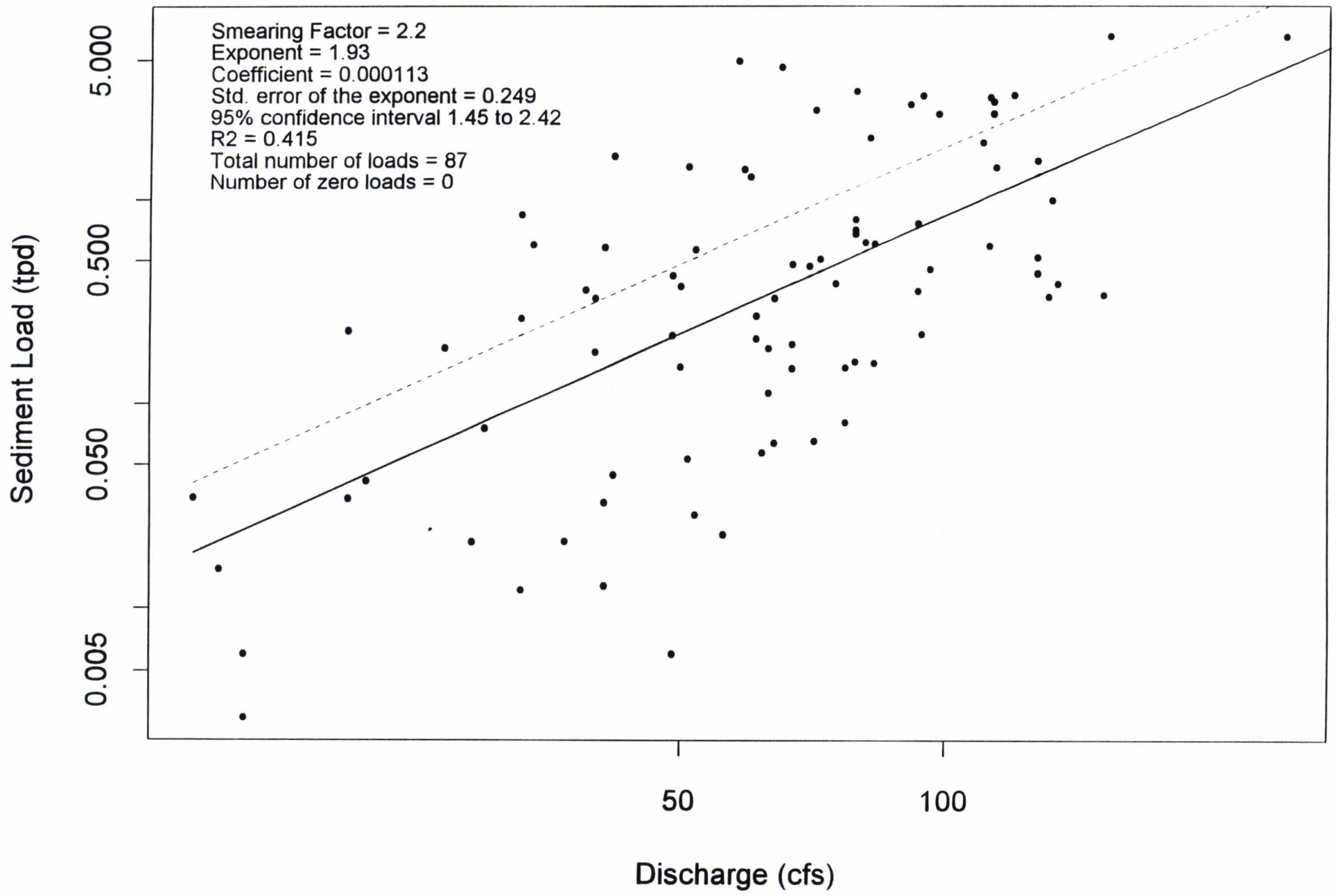
Thu Jan 23 10:49:40 1997

Valley Ck., Bedload > 0.85 mm



Fri Dec 6 13:50:13 1996

WF Buckhorn Bedload > 0.85 mm



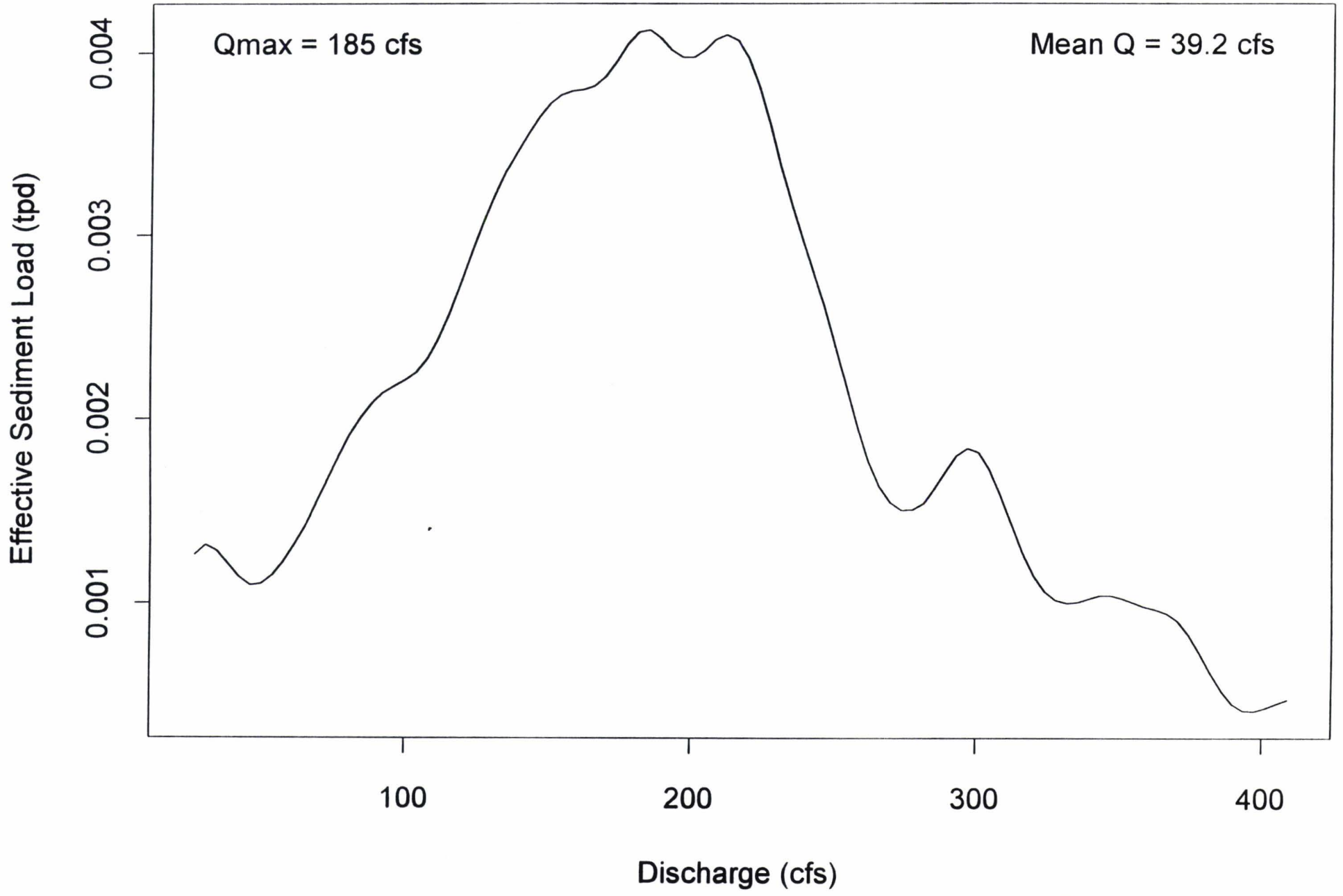
Fri Dec 6 15:15:14 1996

Appendix C -

Effective discharge at sites

Blackmare ext. by SF Salmon 1967-82,86,90-95

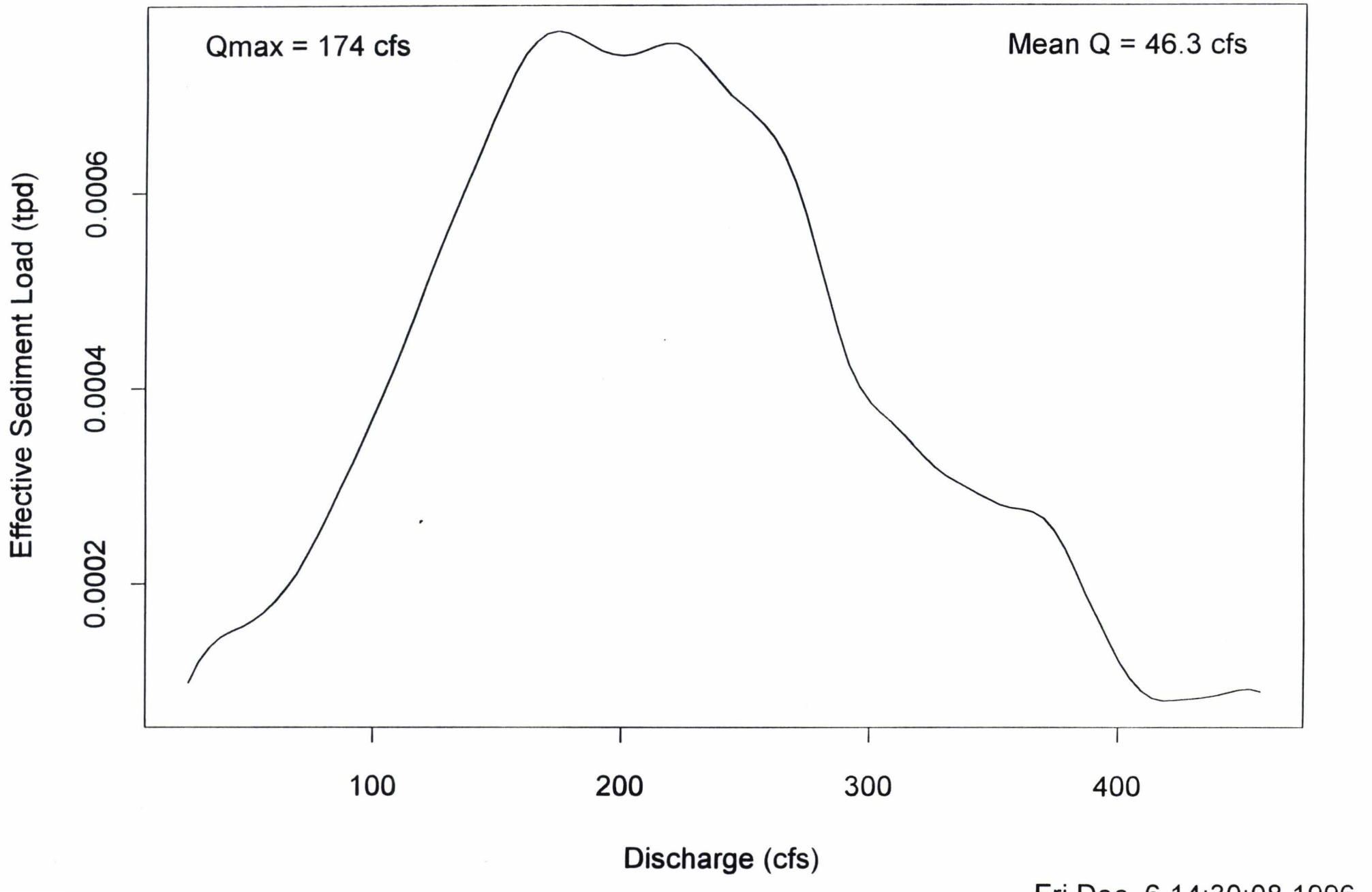
c:/other.str/blackm/blackmve.prn dfactor = 10 Gaussian window Blackmare Ck., Bedload > 0.85



Fri Dec 6 13:52:39 1996

Canyon Ck. ext. by Lochsa 1911-12,30-95

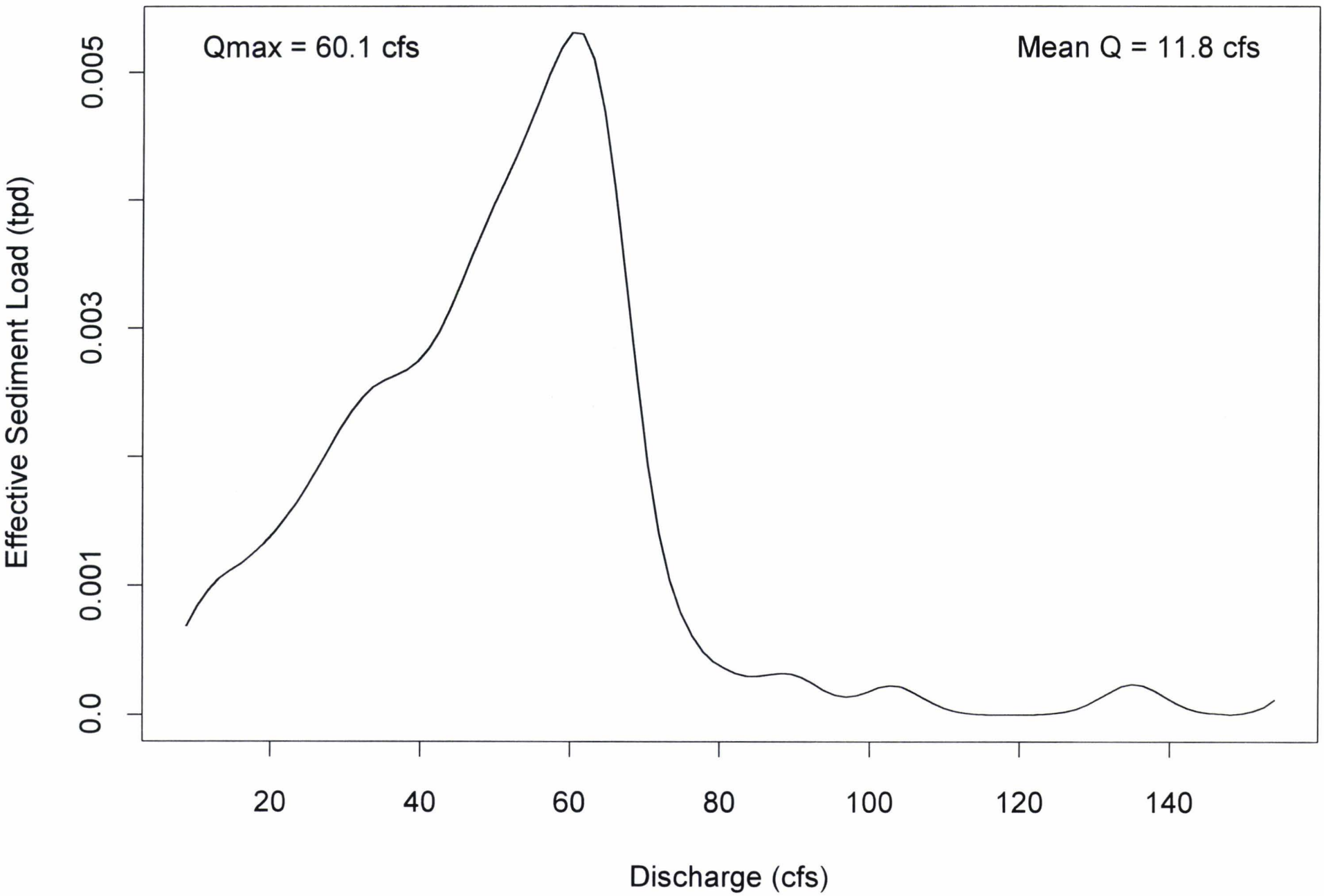
c:/other.str/canyon/canynmve.prn dfactor = 10 Gaussian window Canyon Ck., Bedload > 0.85 m



Fri Dec 6 14:30:08 1996

Catspur Ck. ext. by NF Clearwater 1968-95

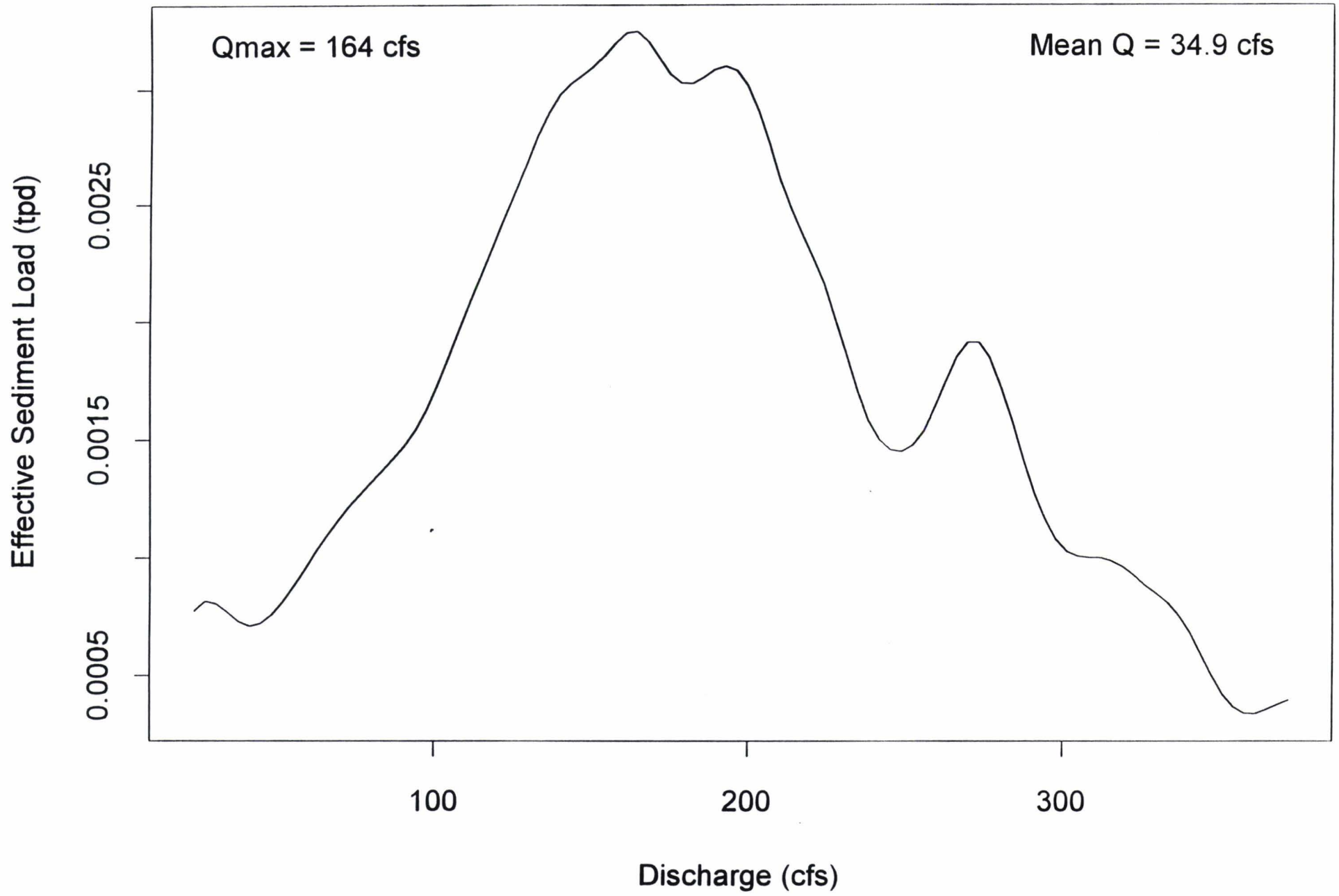
c:/0streams/cats/catsmve.prn dfactor = 10 Gaussian window Catspur Ck., Bedload > 0.85 mm



Tue Feb 4 11:18:18 1997

Dollar Cr. ext. by SF Salmon 1967-82,86,90-95

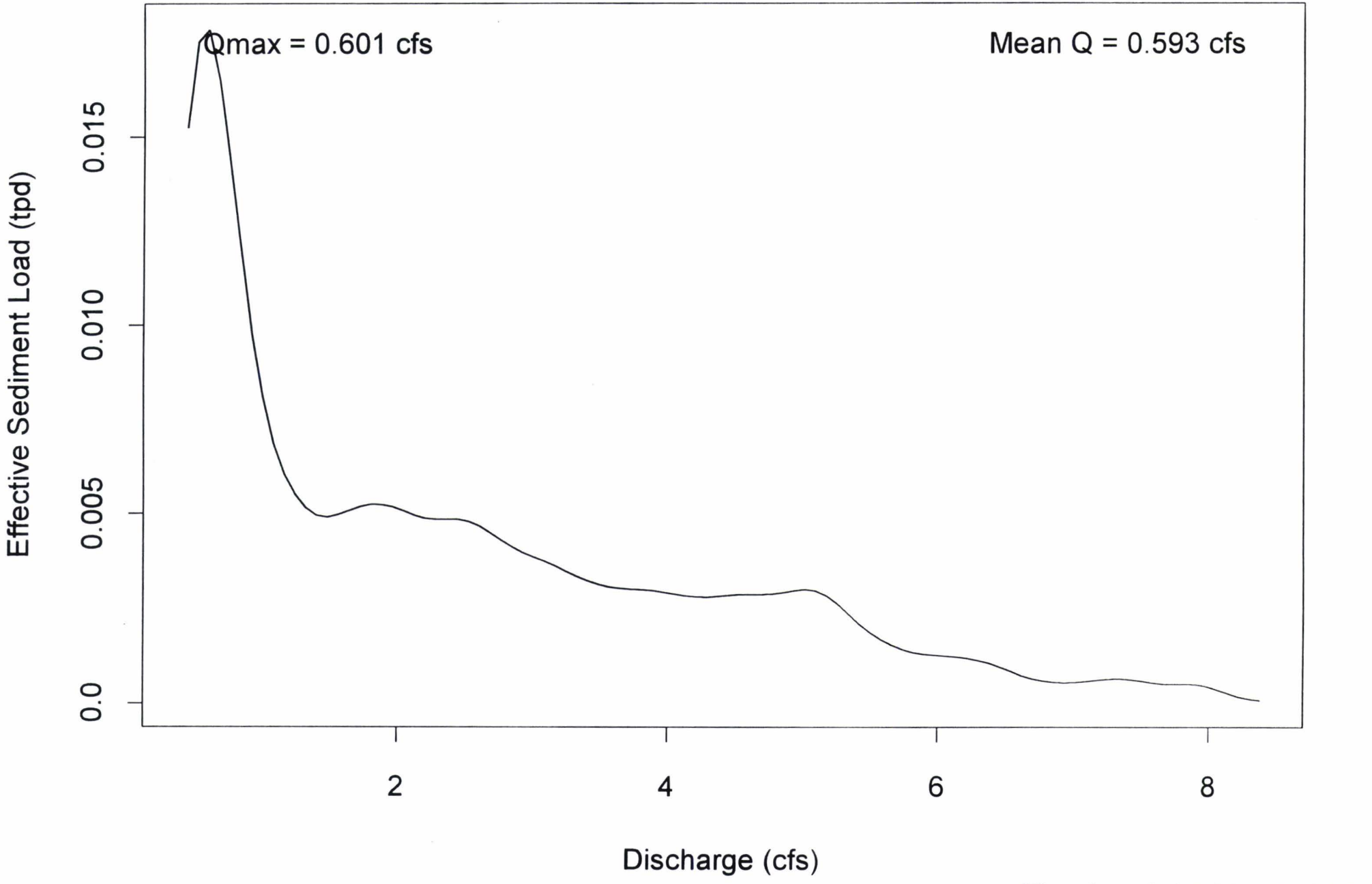
c:/other.str/dollar/dollmve.prn dfactor = 10 Gaussian window Dollar Ck., Bedload > 0.85 mm



Fri Dec 6 14:38:47 1996

Eggers Ck. 1966-93

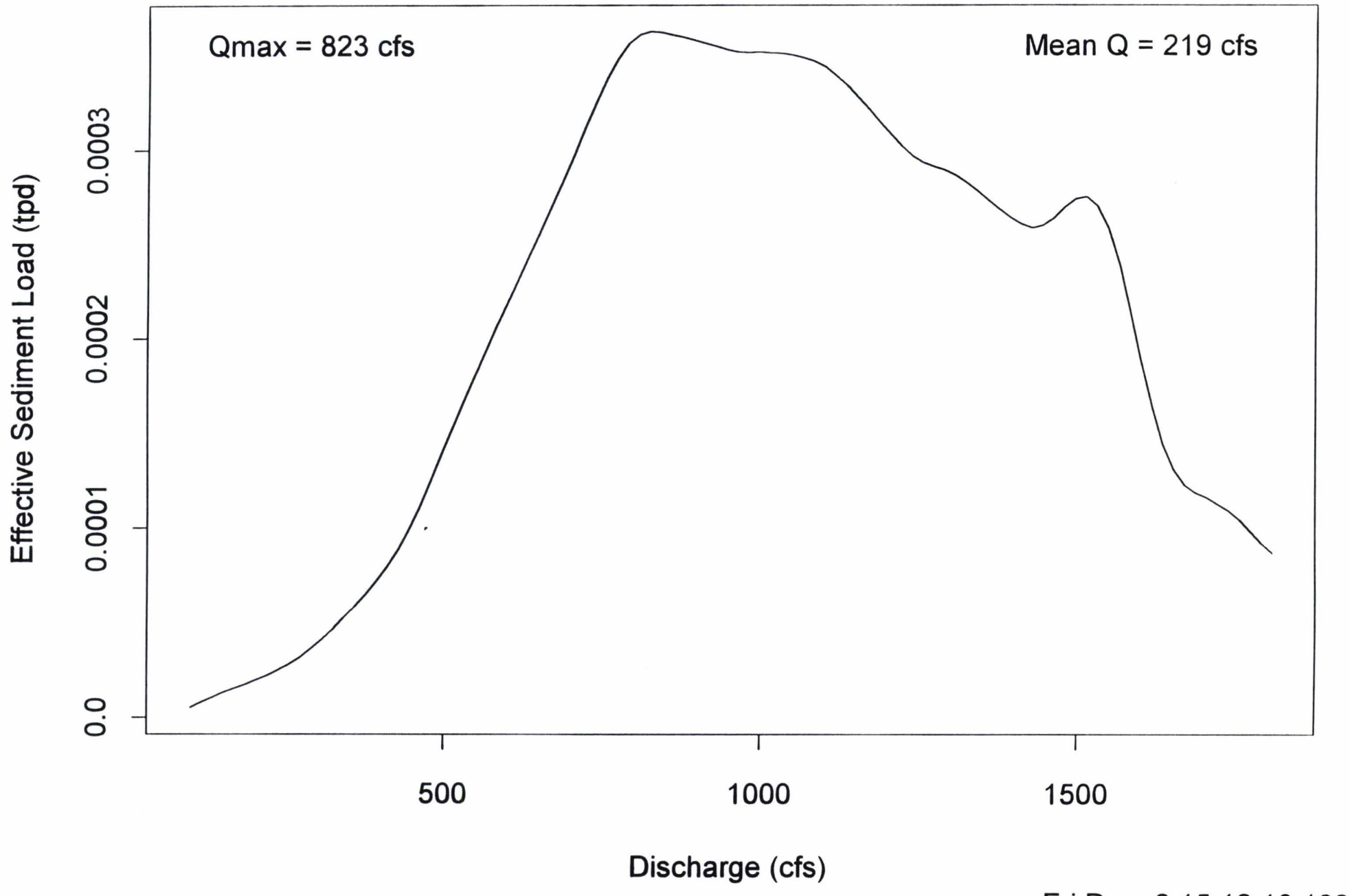
c:/0streams/egger/eggerqqq.prn dfactor = 10 Gaussian window Eggers Ck. Bedload, All sizes



Thu Jan 9 16:29:47 1997

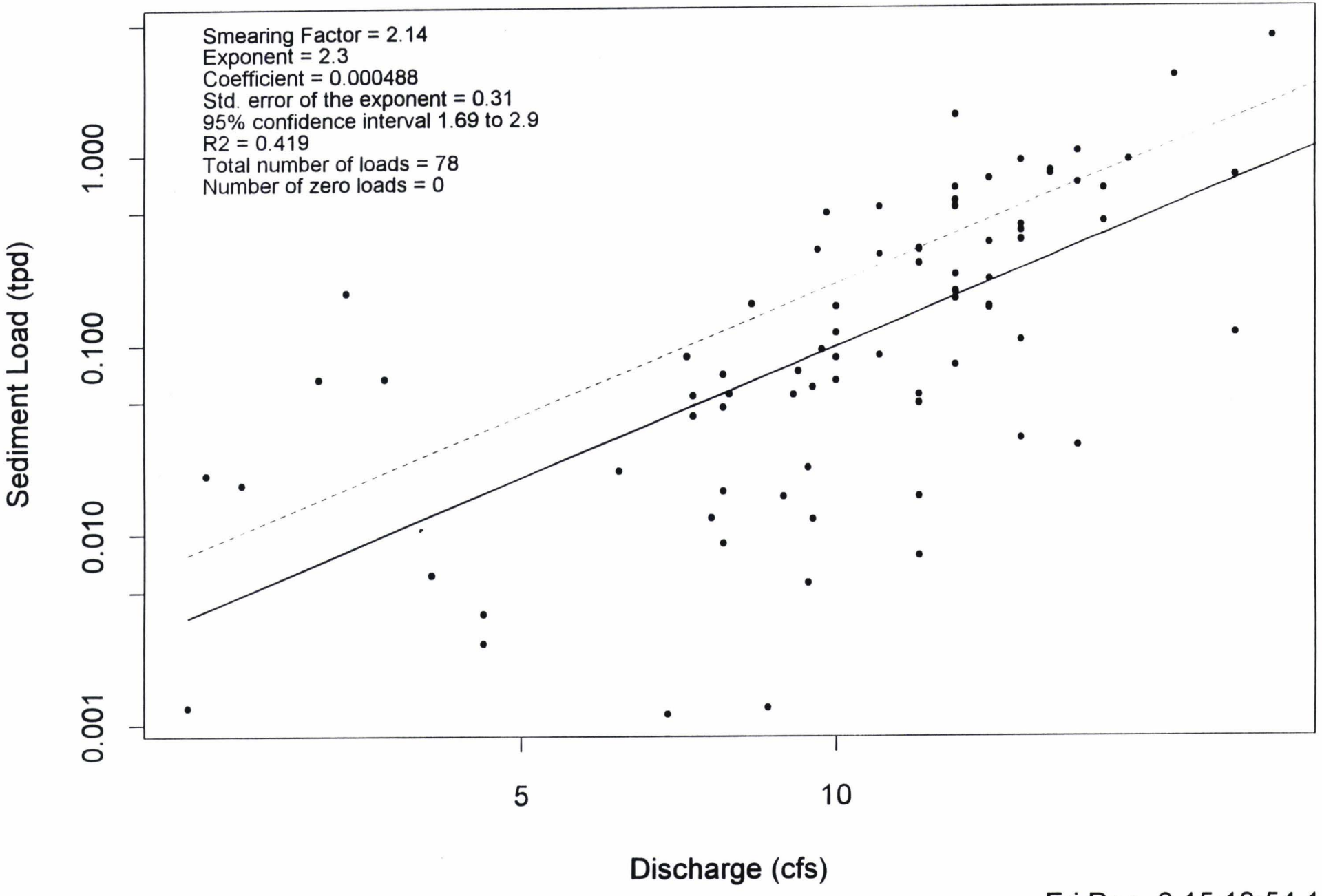
Fish Ck. ext by Lochsa 1911-12,30-95

c:/other.str/fish/fishmve.prn dfactor = 10 Gaussian window Fish Ck., Bedload > 0.85 mm



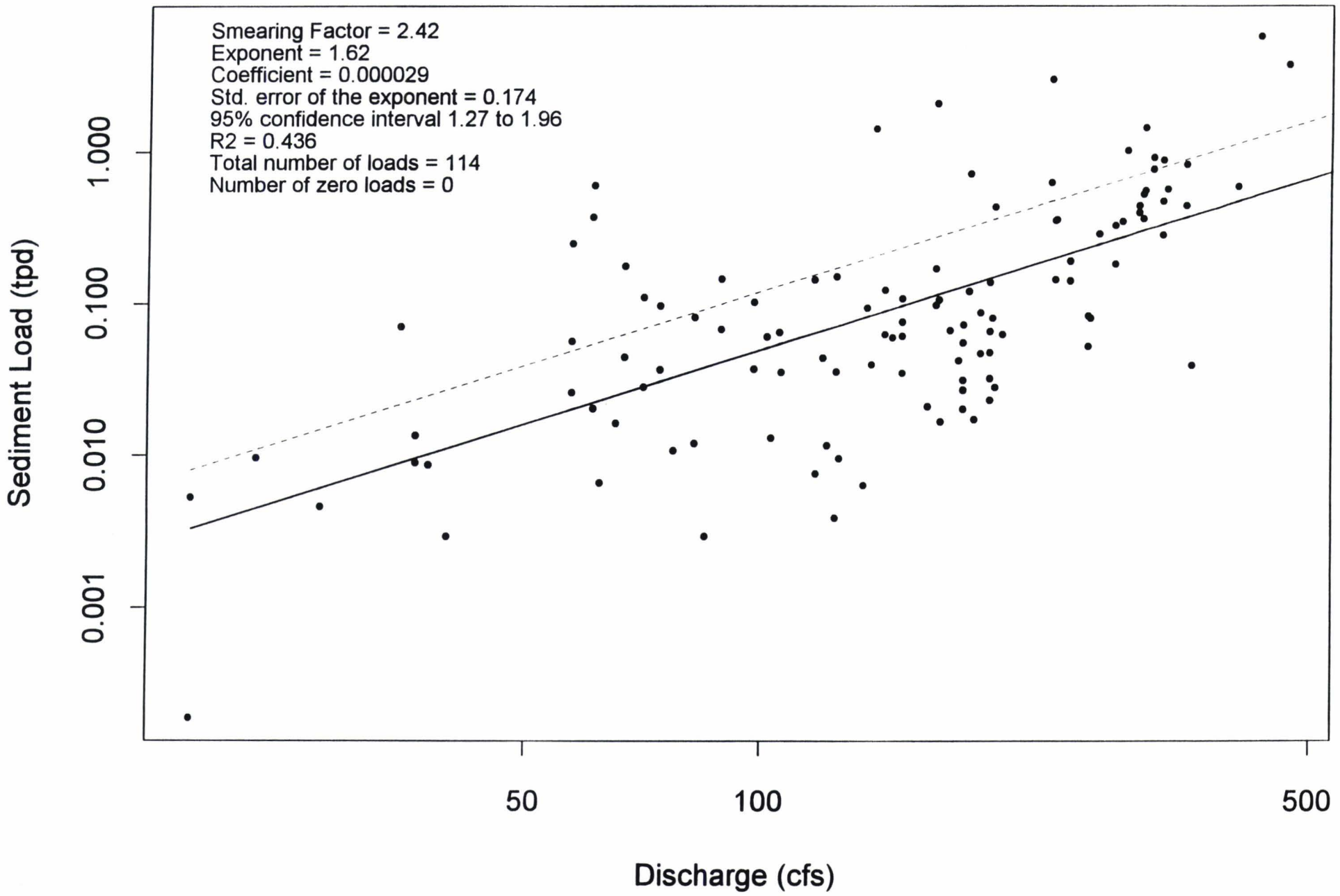
Fri Dec 6 15:12:10 1996

Little Buckhorn, Bedload > 0.85 mm



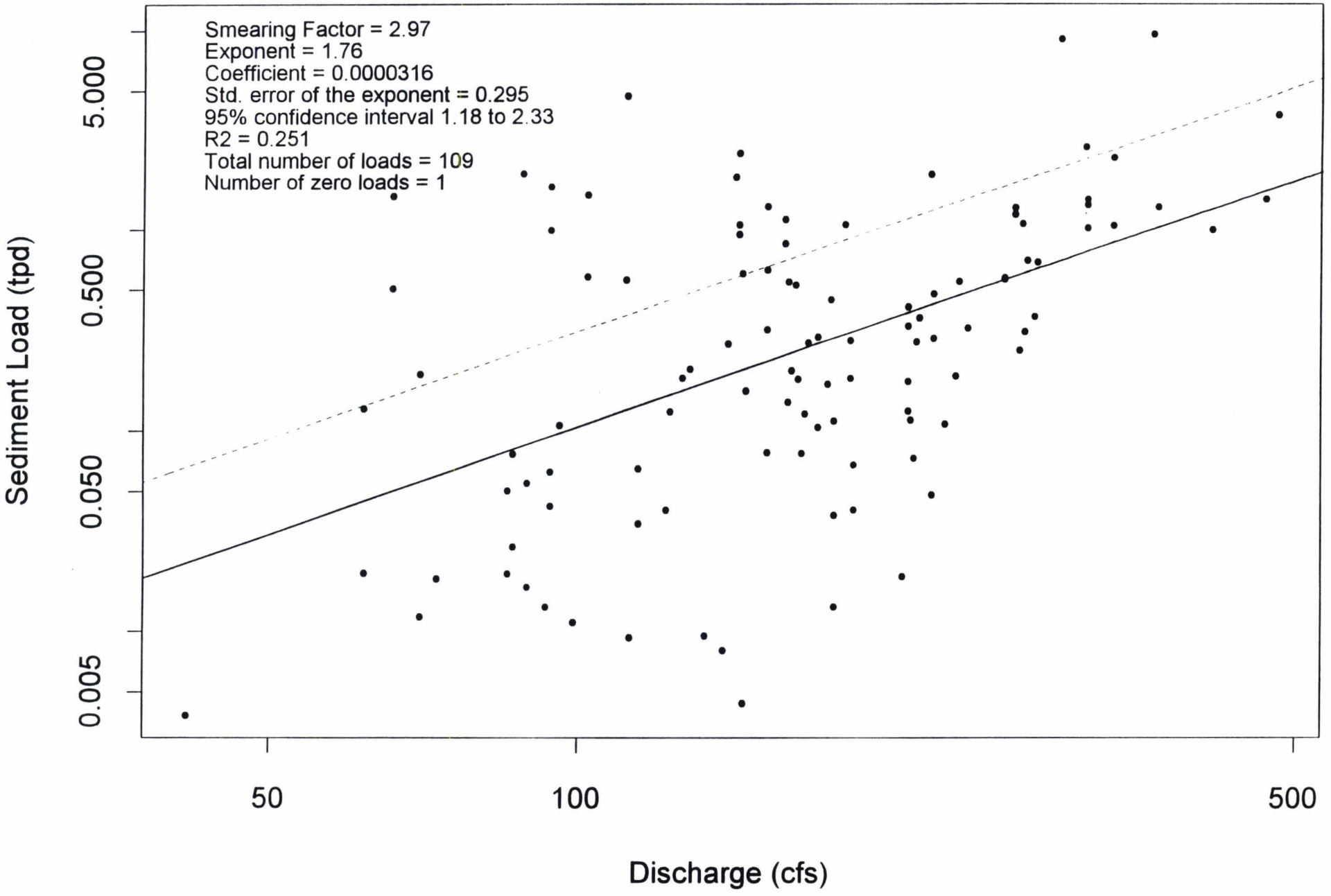
Fri Dec 6 15:13:54 1996

Little Slate Ck, Bedload > 0.85 mm



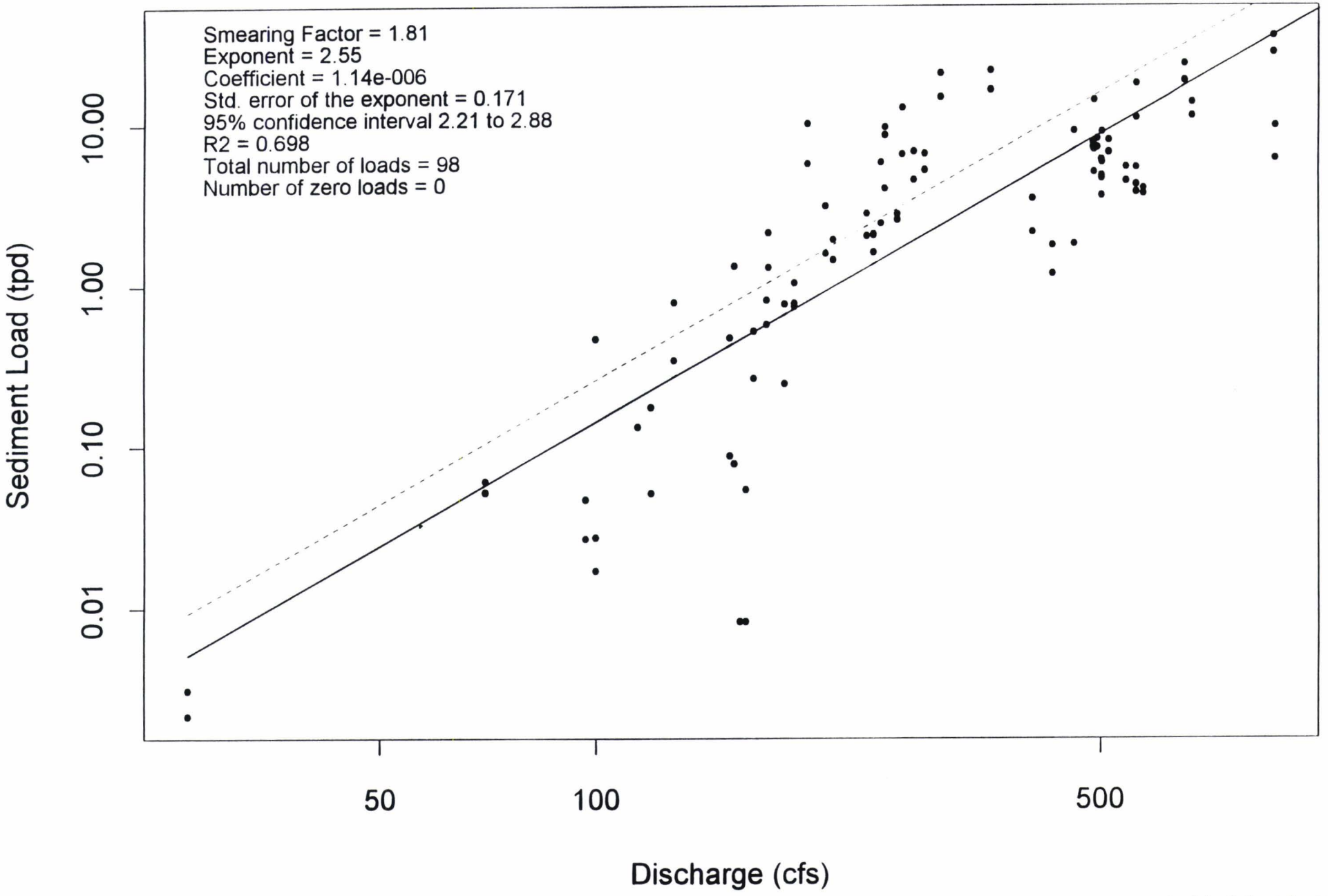
Wed Jan 22 21:54:14 1997

Lolo Ck., Bedload > 0.85 mm

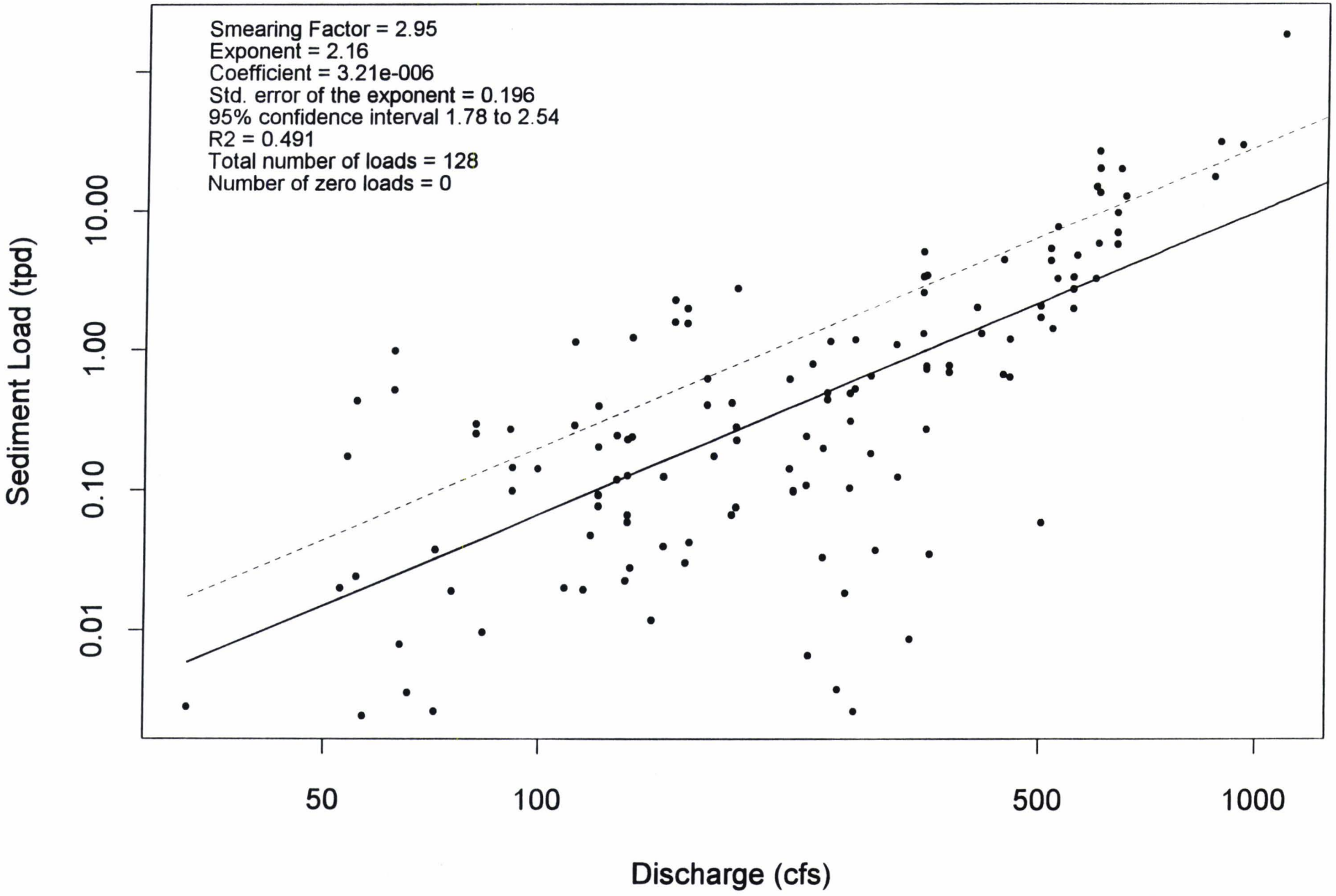


Thu Jan 23 14:35:39 1997

Marsh Ck., Bedload > 0.85 mm

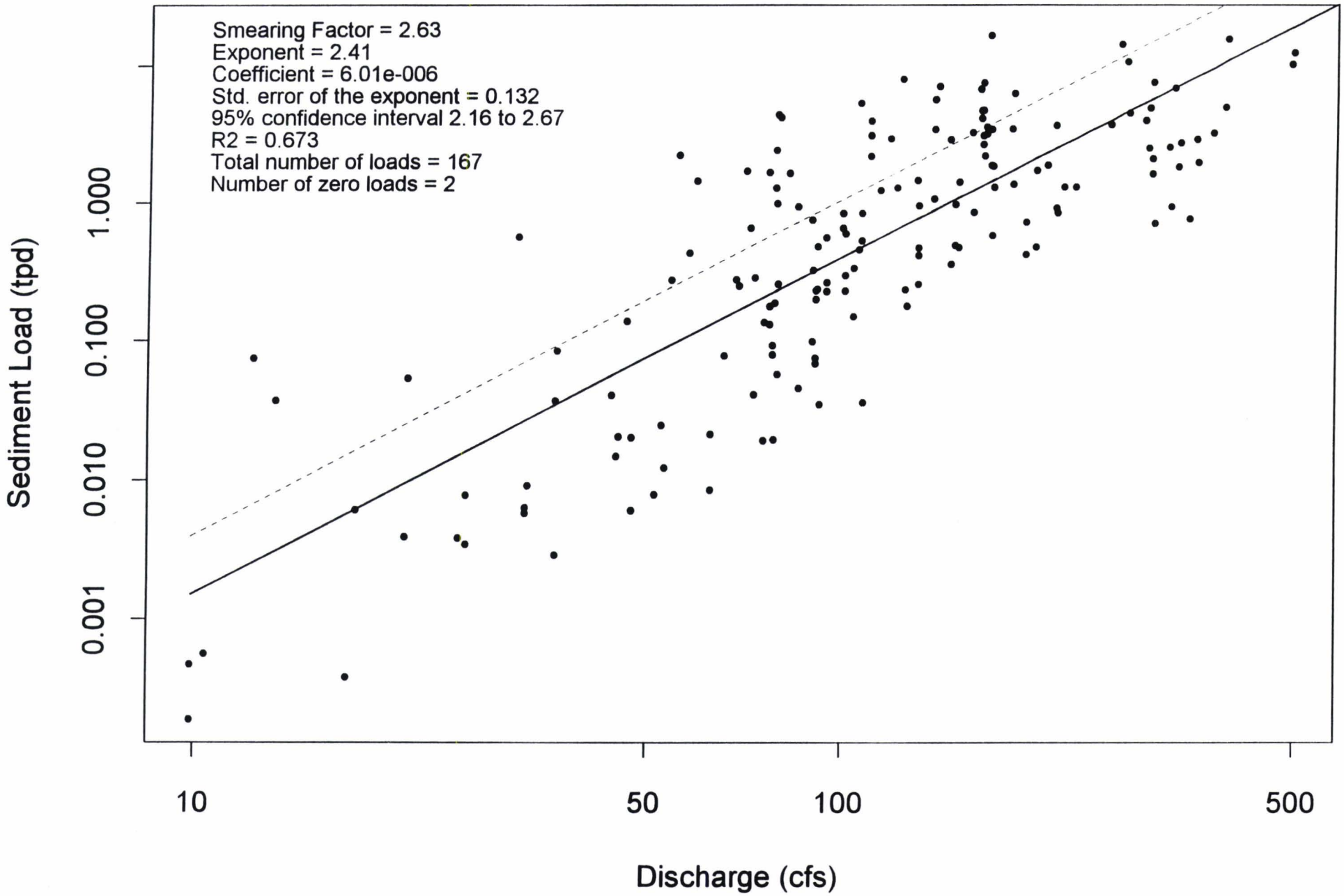


Rapid R., Bedload > 0.85 mm



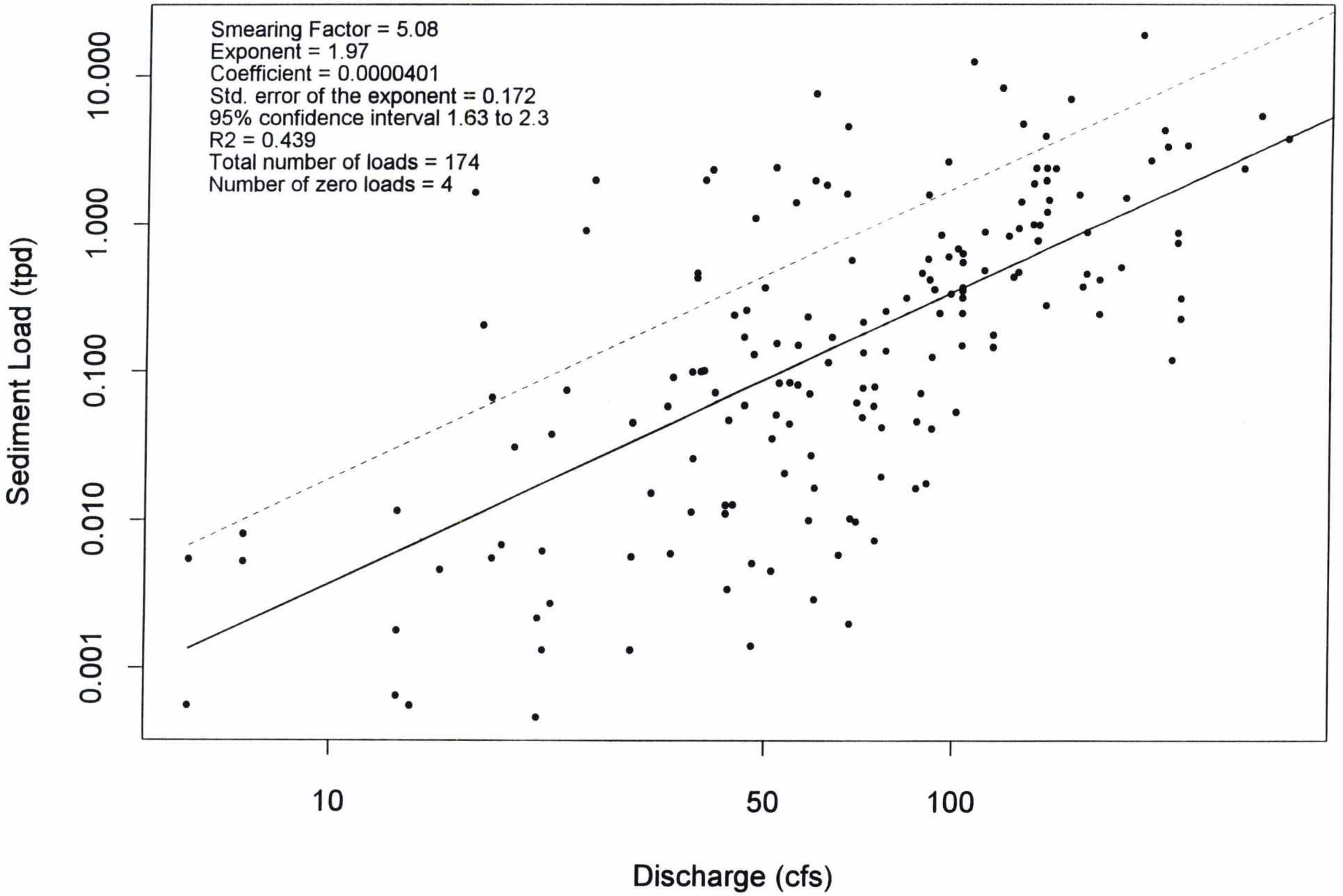
Wed Jan 22 21:56:36 1997

Red R., Bedload > 0.85 mm



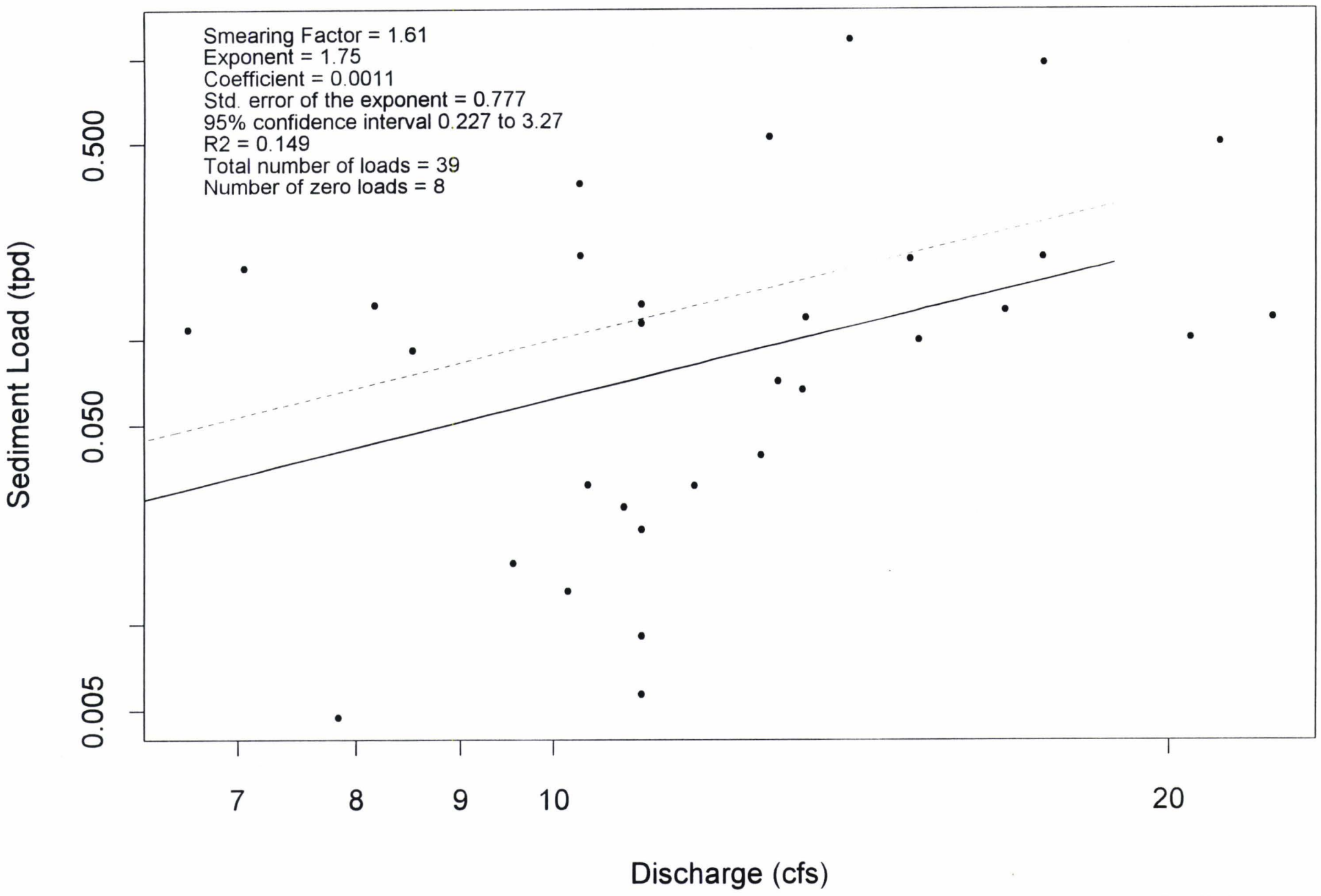
Wed Jan 22 21:57:53 1997

South Fork Red R., Bedload > 0.85 mm



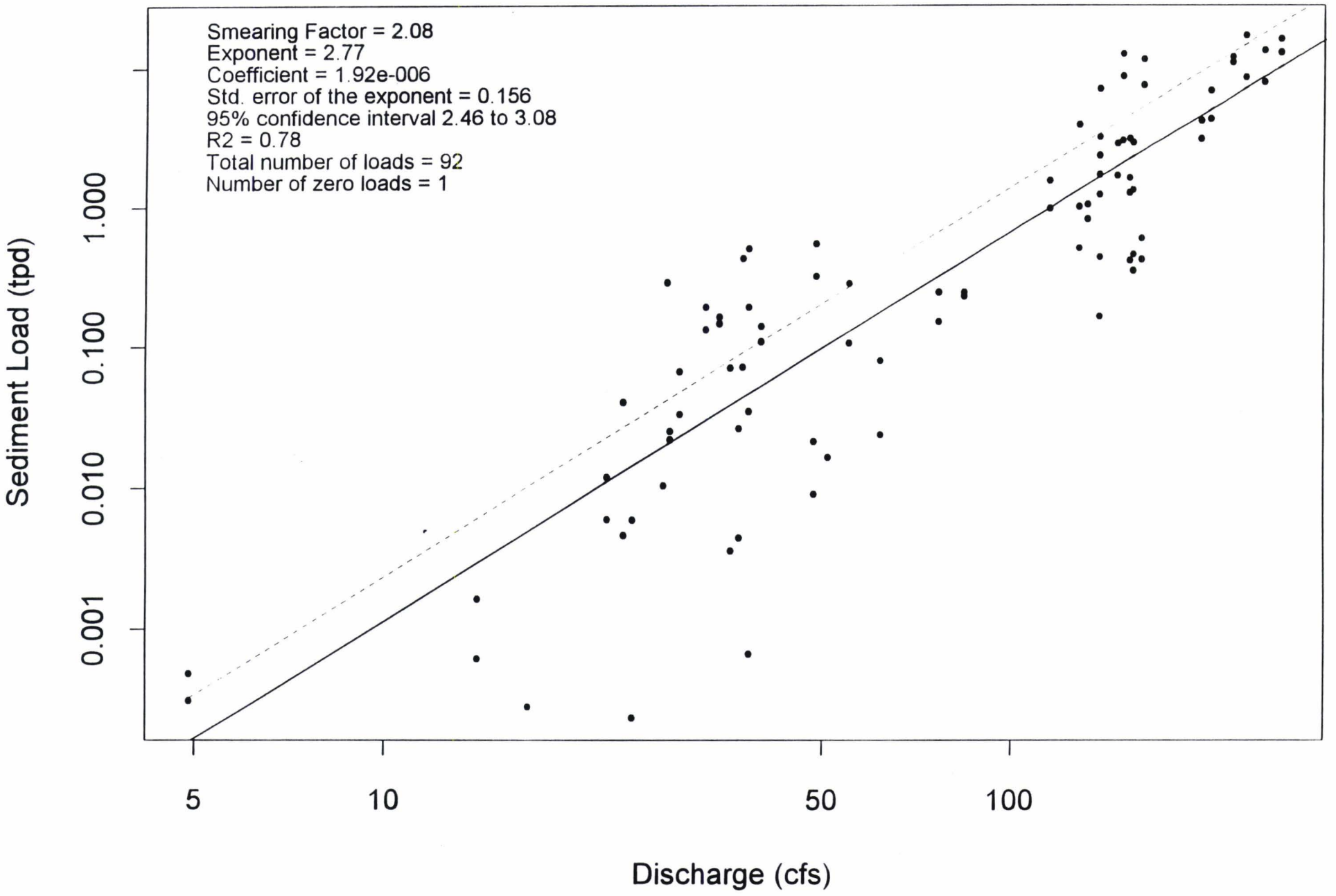
Wed Jan 22 21:58:32 1997

Squaw Ck (USFS) Bedload > 0.85 mm



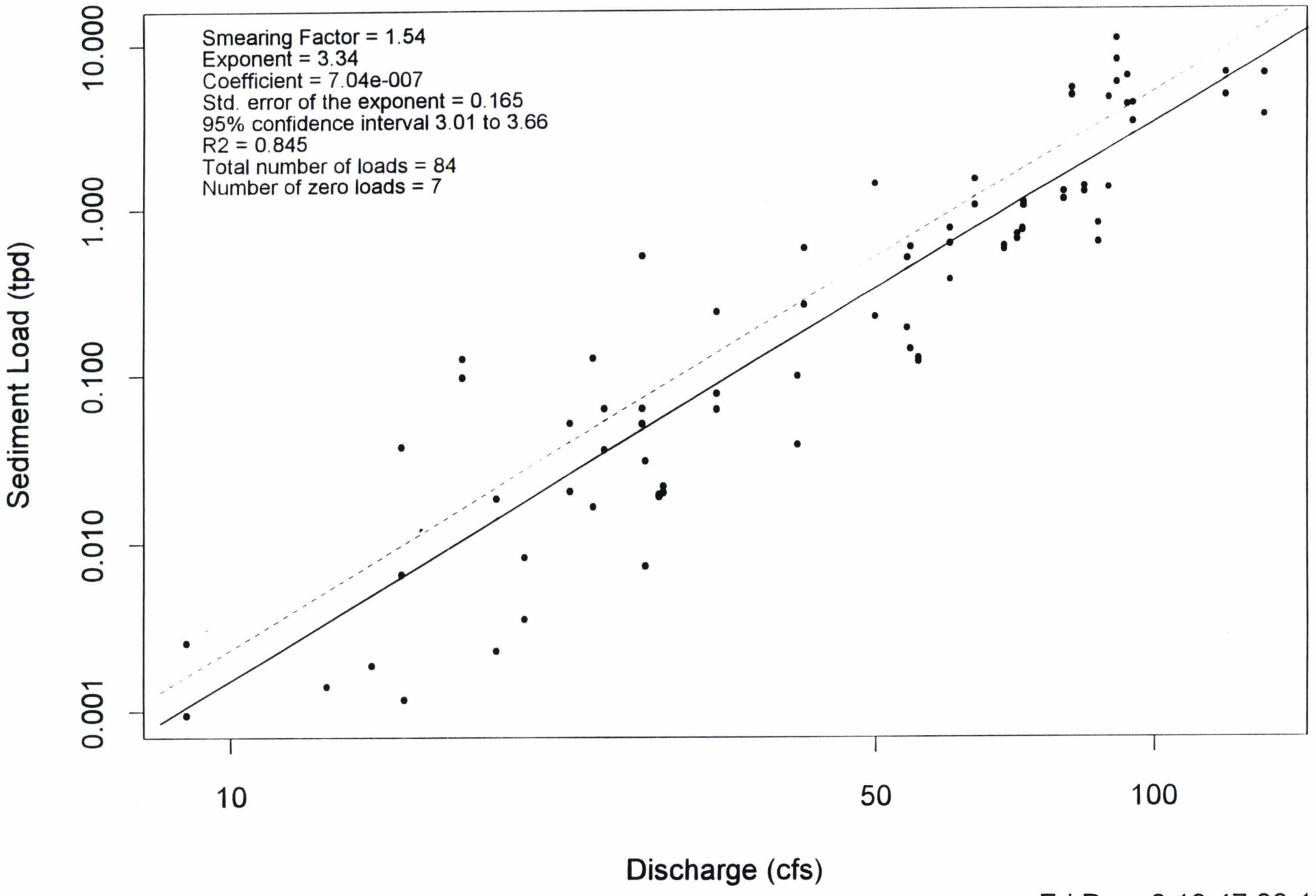
Thu Jan 9 15:55:20 1997

Squaw Creek, Bedload > 0.85 mm



Fri Dec 6 13:42:38 1996

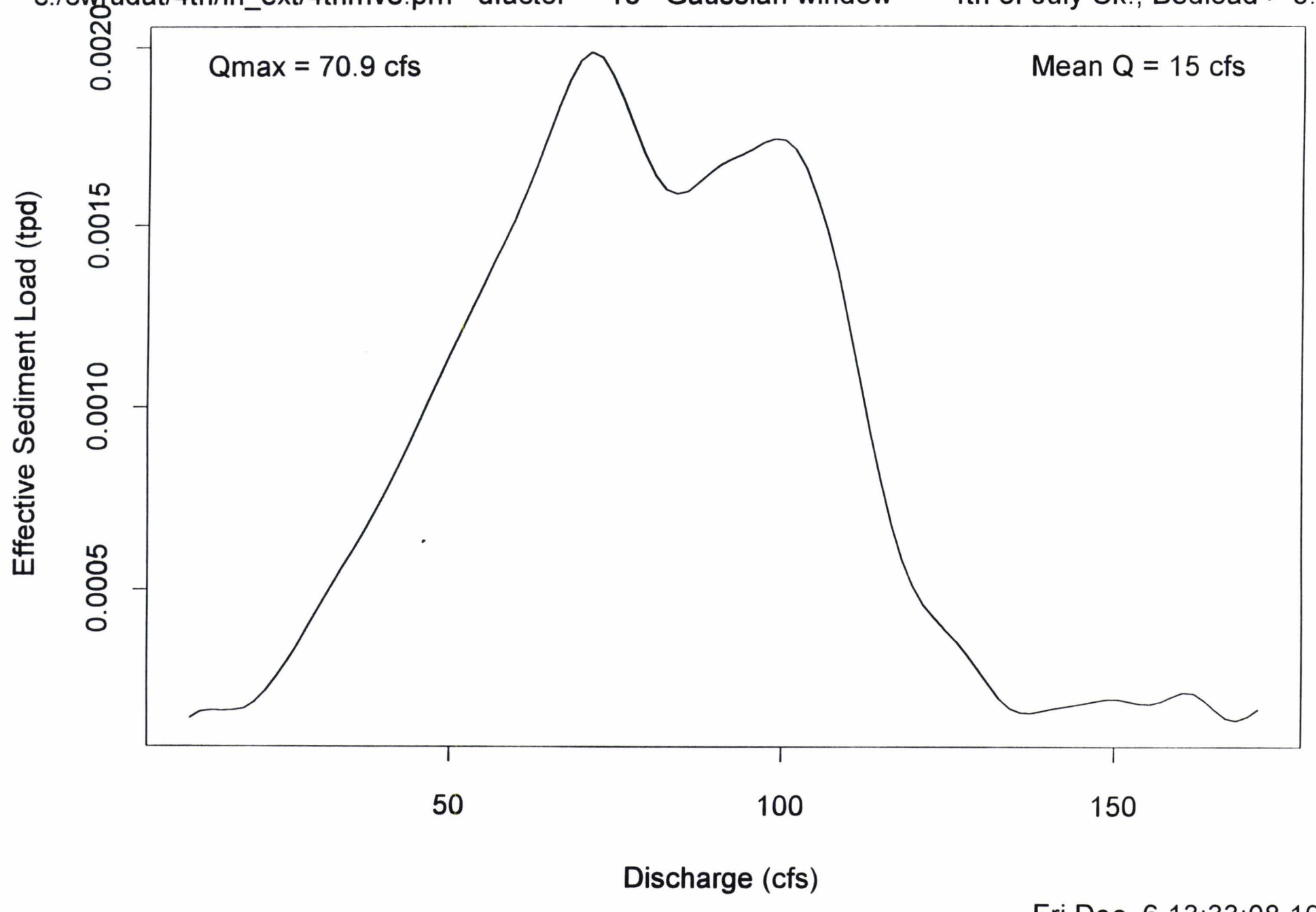
Thompson Ck., Bedload > 0.85 mm



Fri Dec 6 13:47:33 1996

4th of July Ck., Ext. by Valley 1912-13,22-71,93-95, ln transform

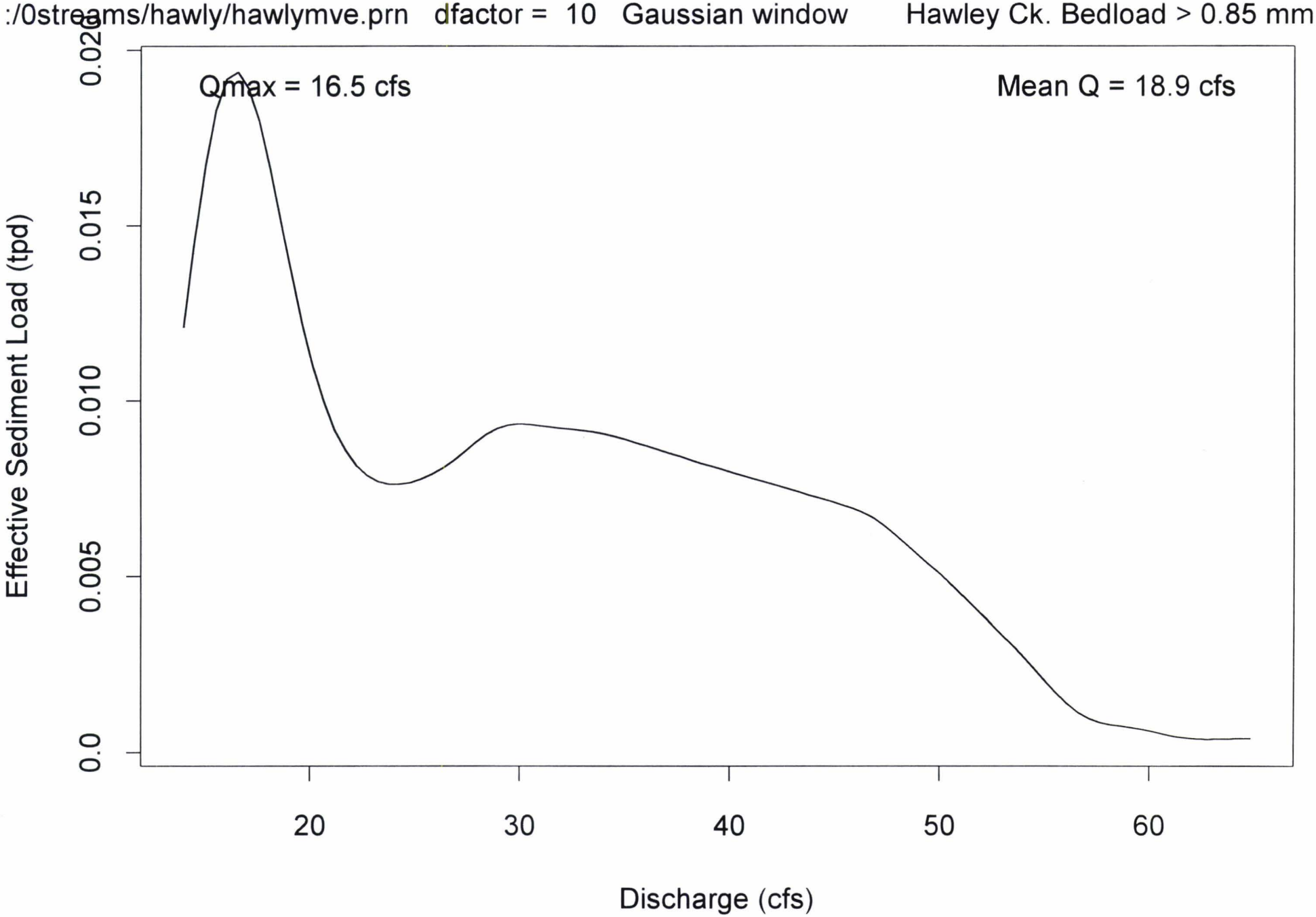
c:/cwrudat/4th/ln_ext/4thmve.prn dfactor = 10 Gaussian window 4th of July Ck., Bedload > 0.85 m



Fri Dec 6 13:33:08 1996

Hawley Ck ext. by Squaw (USGS) 1973-95

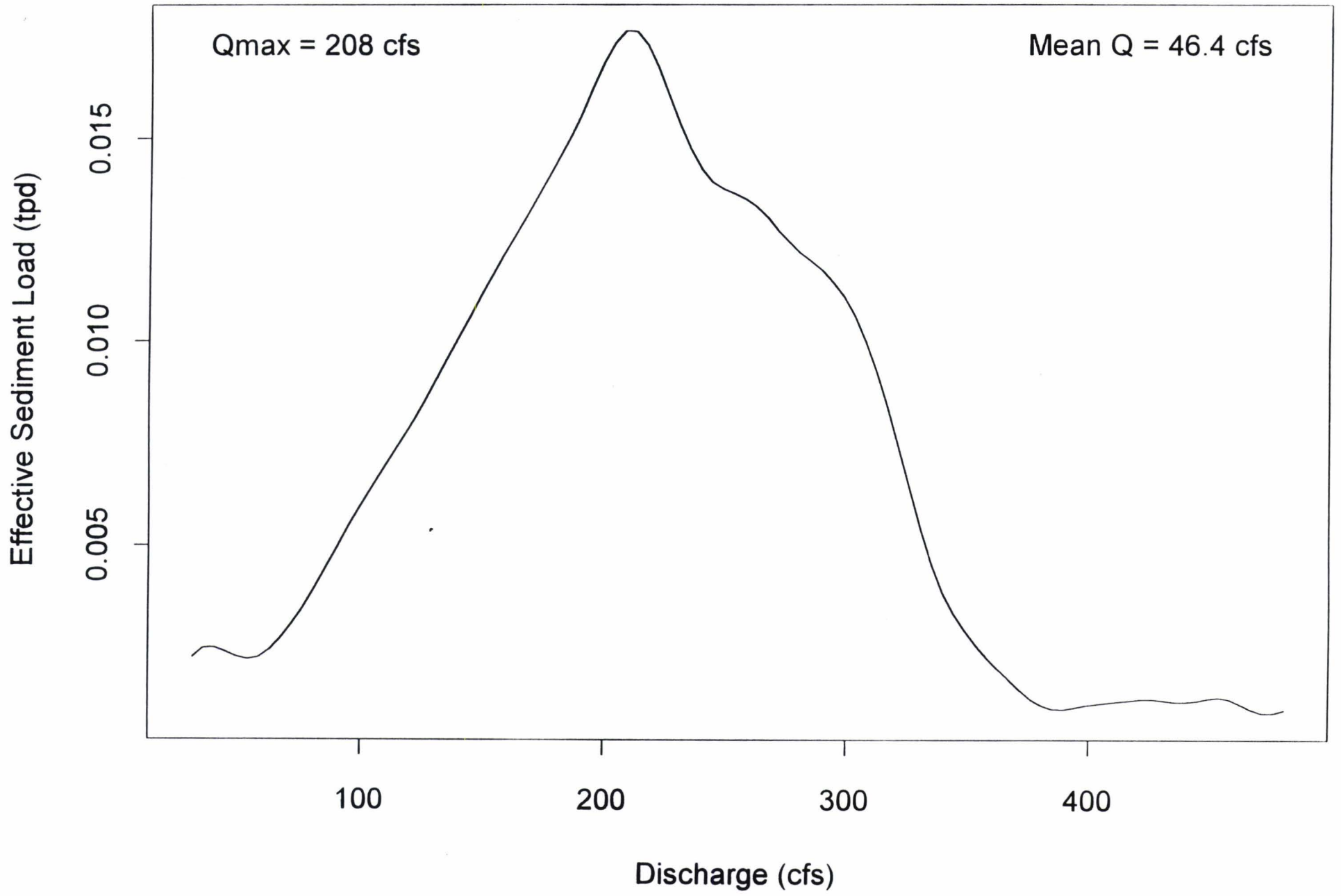
:/0streams/hawly/hawlymve.prn dfactor = 10 Gaussian window Hawley Ck. Bedload > 0.85 mm 199



Fri Jan 10 16:02:22 1997

Herd Ck. ext. by Valley 1912-13,22-71,93-95

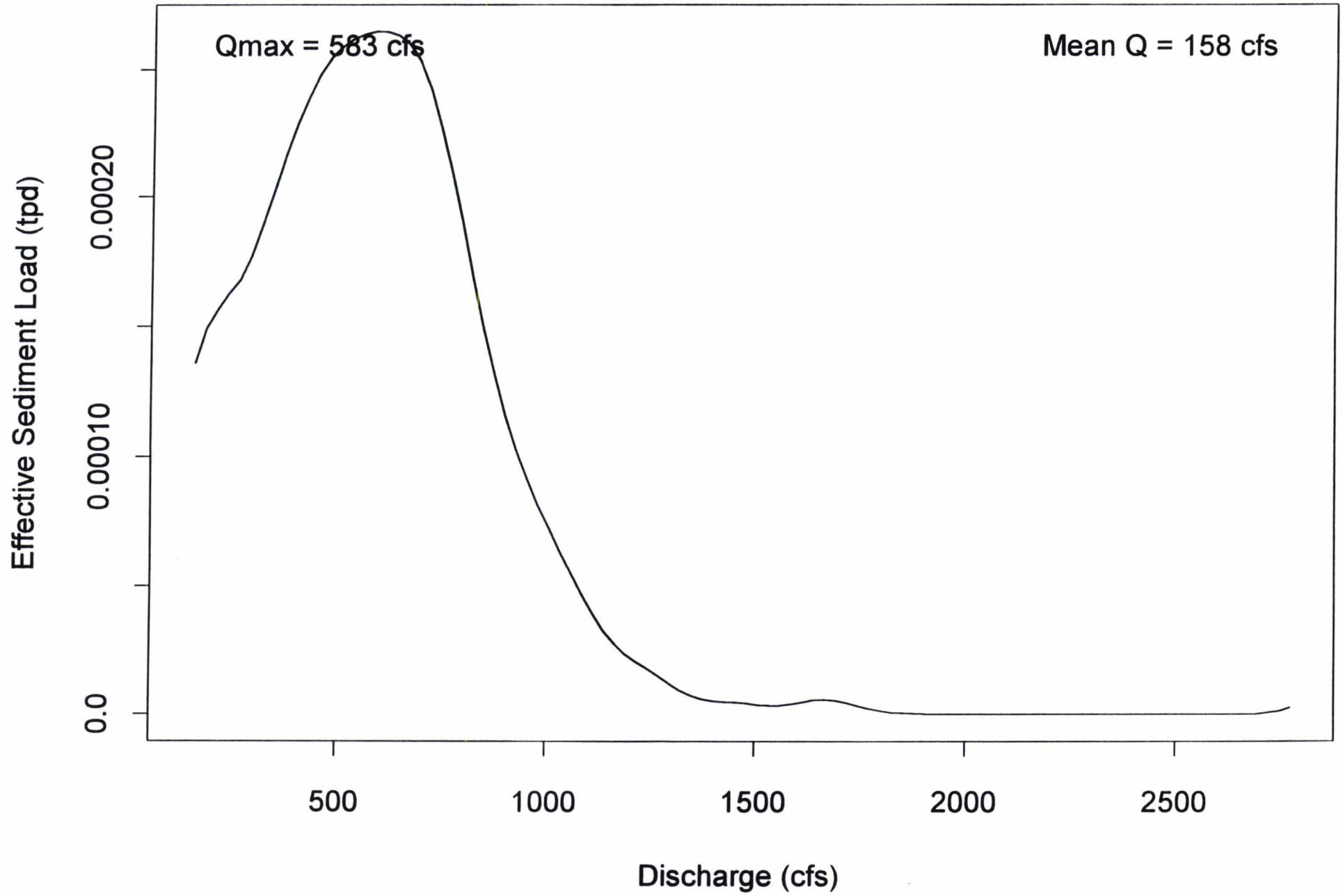
c:/cwrudat/herd/herdext.prn dfactor = 10 Gaussian window Herd Ck., Bedload > 0.85 mm



Fri Dec 6 13:37:07 1996

Johns Ck. ext. by Clearwater at Stites 1965-95

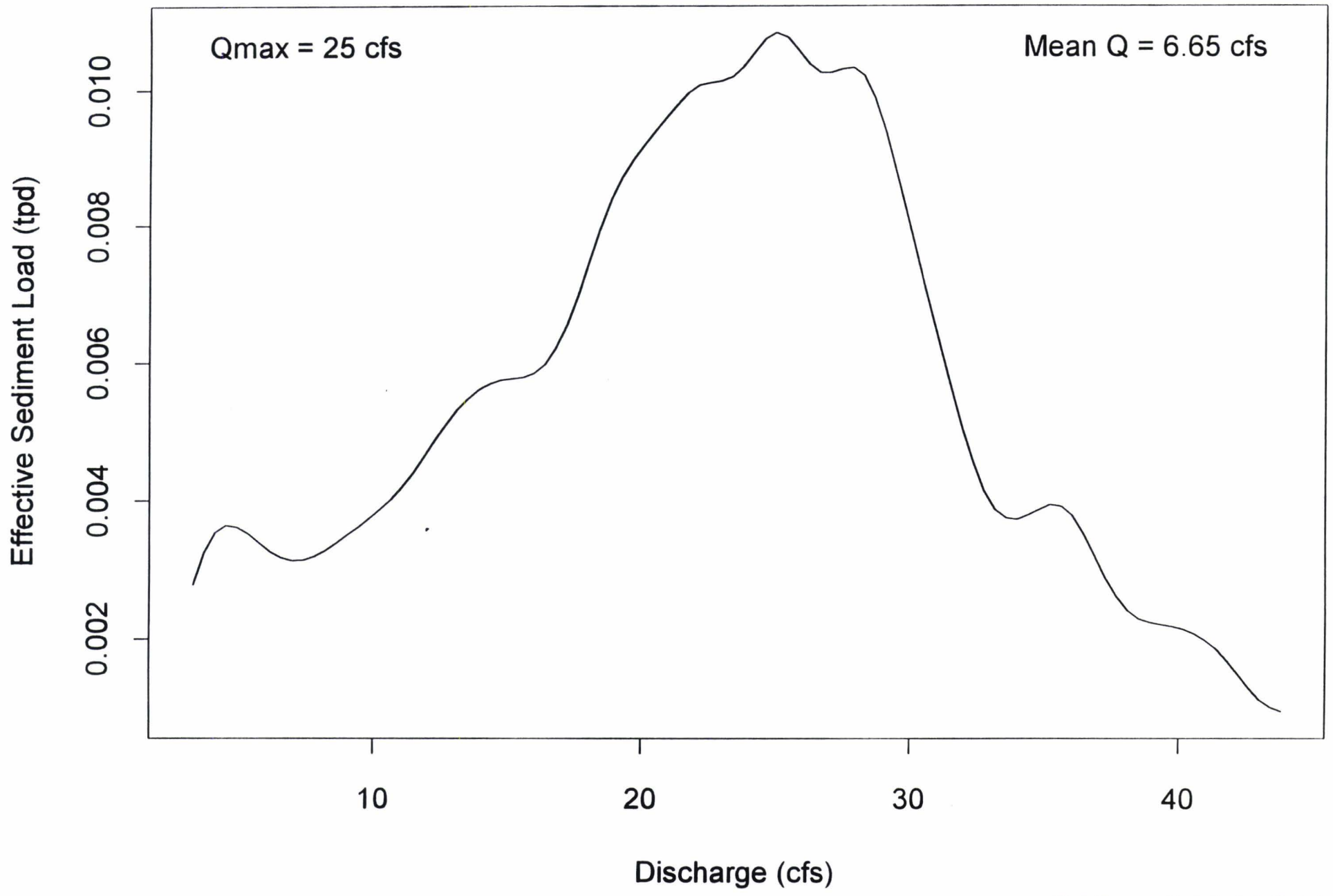
c:/00snake/johns/johnsmve.prn dfactor = 10 Gaussian window Johns Ck, Bedload > 0.85mm



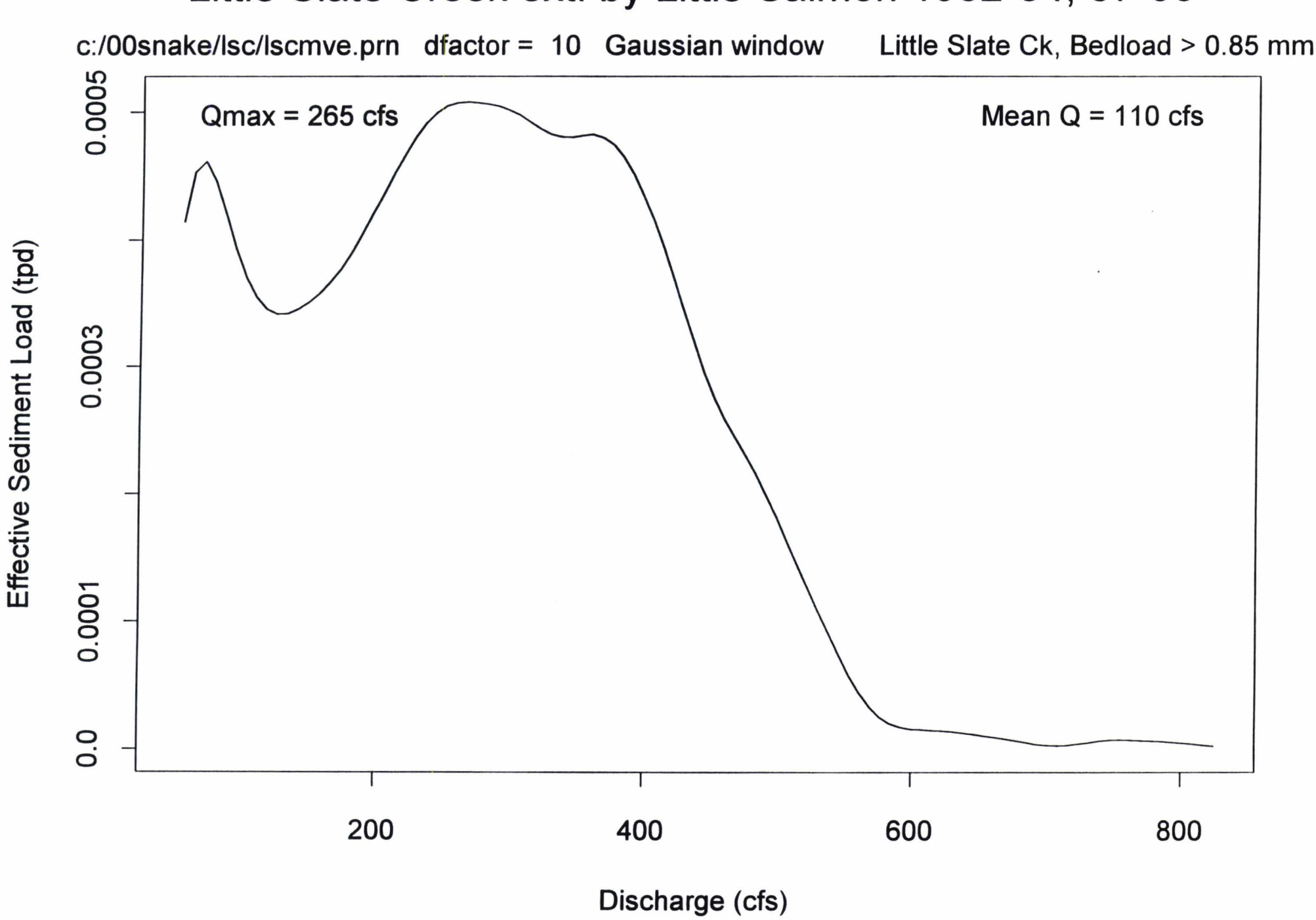
Wed Jan 22 21:51:06 1997

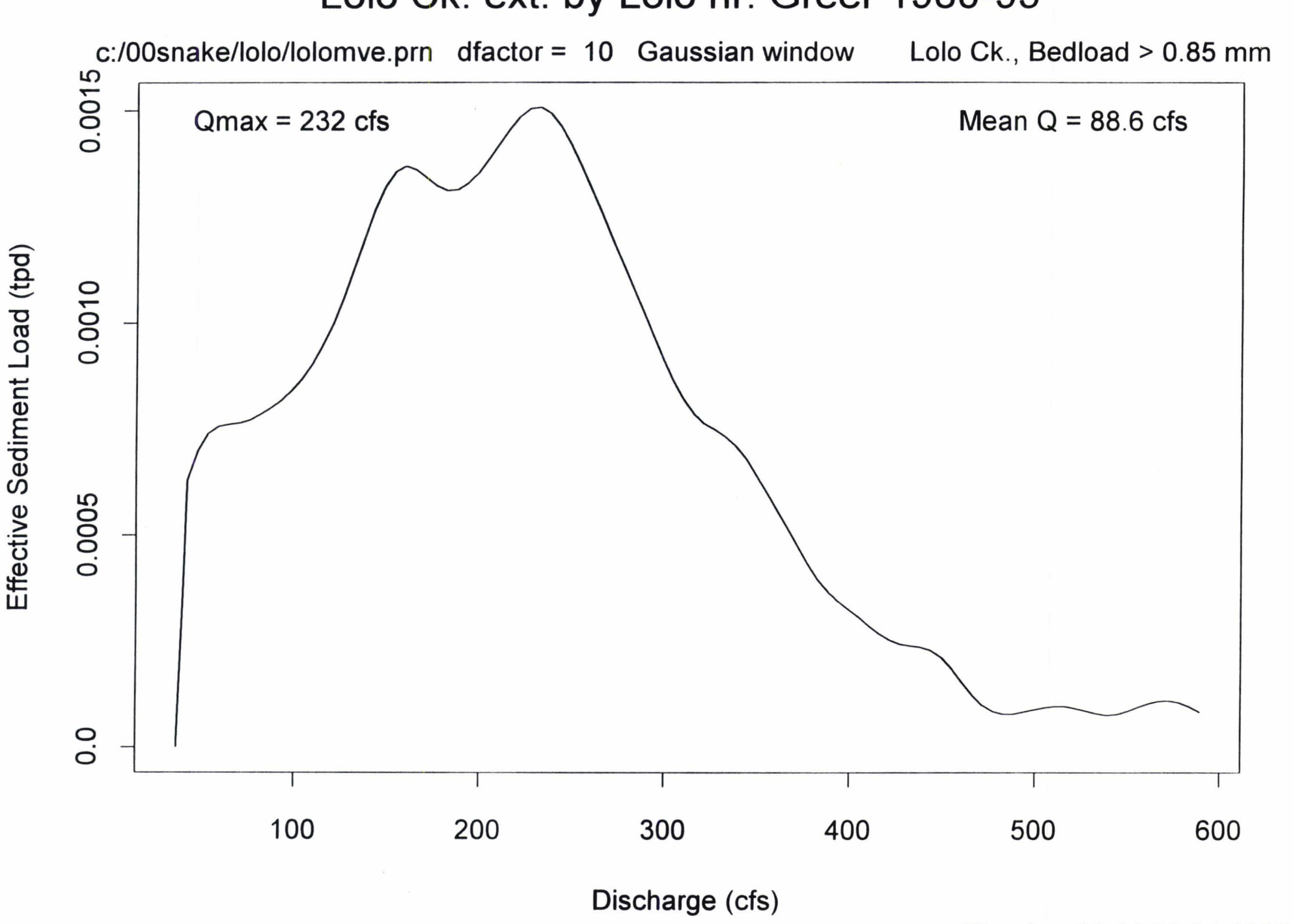
Little Buckhorn ext. by SF Salmon 1967-82,86,90-95

c:/other.str/lbuck/lbuckmve.prn dfactor = 10 Gaussian window Little Buckhorn, Bedload > 0.85 m



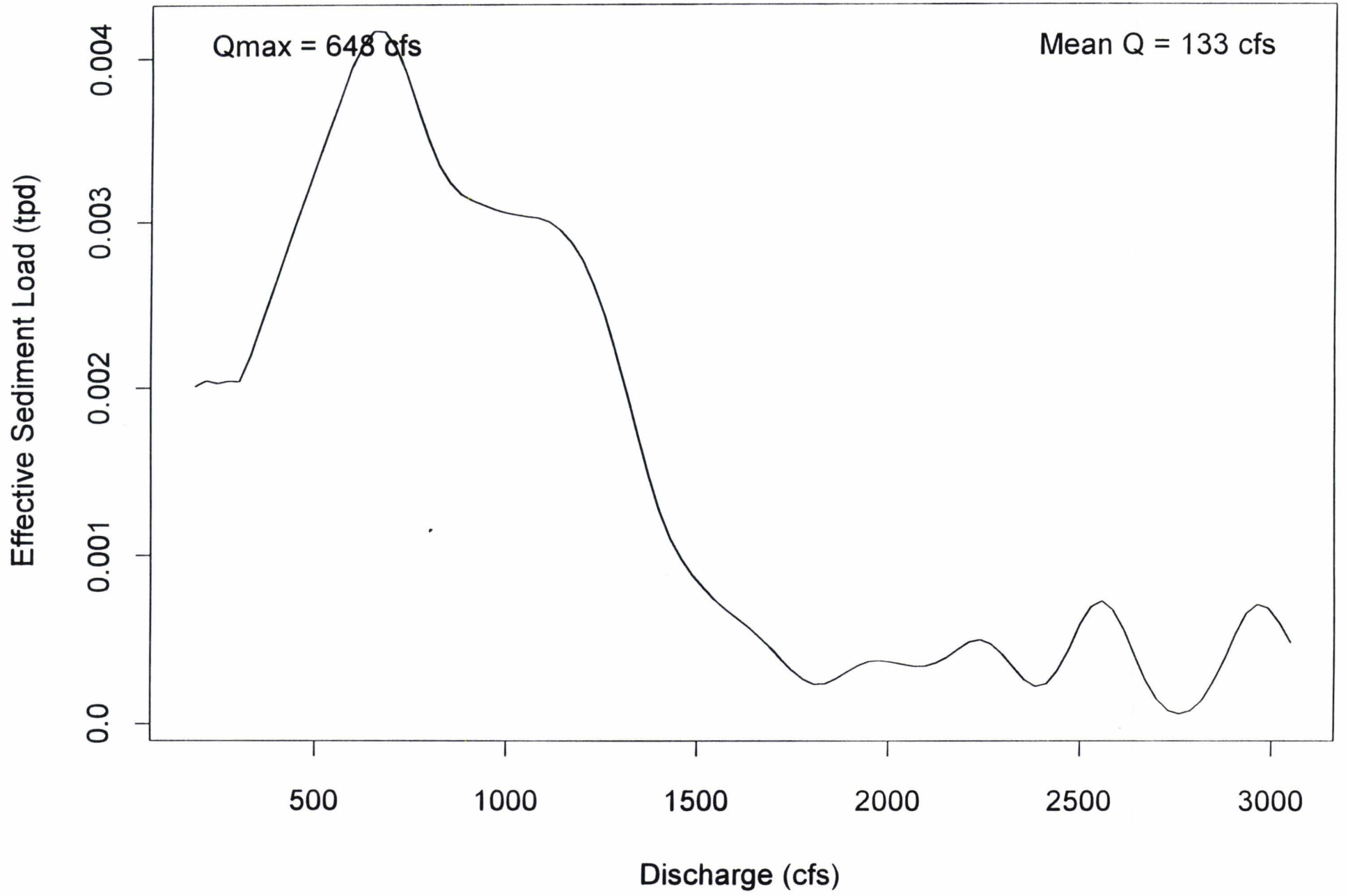
Fri Dec 6 15:14:04 1996


Little Slate Creek ext. by Little Salmon 1952-54, 57-95
c:/00snake/lsc/lscmve.prn dfactor = 10 Gaussian window
Little Slate Ck, Bedload > 0.85 mm
Qmax = 265 cfs
Mean Q = 110 cfs
Effective Sediment Load (tpd)
0.0
0.0001
0.0003
0.0005
200
400
600
800
Discharge (cfs)
Wed Jan 22 21:54:23 1997


Lolo Ck. ext. by Lolo nr. Greer 1980-95
c:/00snake/lolo/lolomve.prn dfactor = 10 Gaussian window
Lolo Ck., Bedload > 0.85 mm
Qmax = 232 cfs
Mean Q = 88.6 cfs
Effective Sediment Load (tpd)
0.0
0.0005
0.0010
0.0015
100
200
300
400
500
600
Discharge (cfs)
Thu Jan 23 14:36:04 1997

Marsh Ck. ext. by Valley 1912-13,22-71,93-95

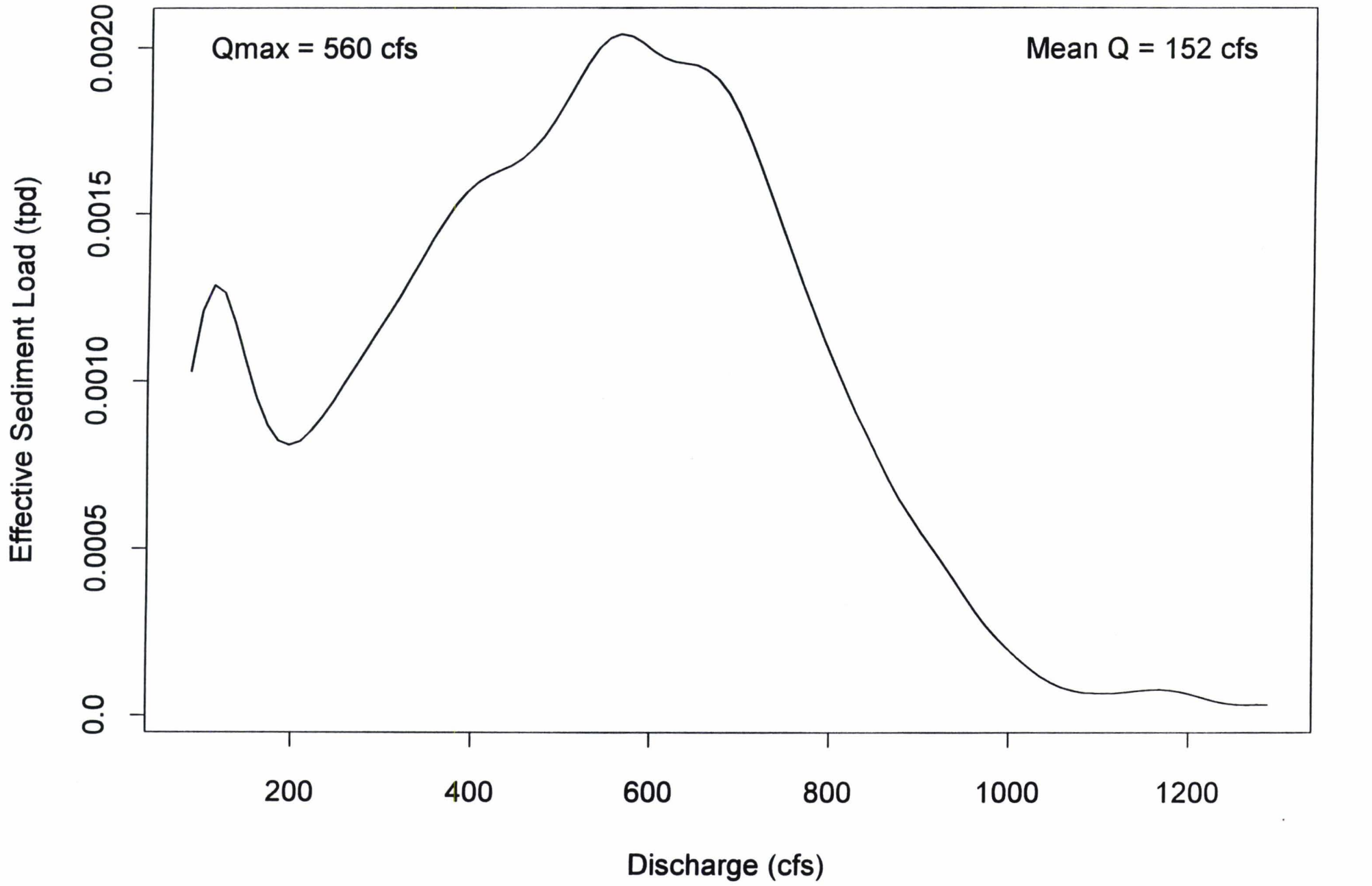
c:/cwrudat/marsh/marshext.prn dfactor = 10 Gaussian window Marsh Ck., Bedload > 0.85 mm



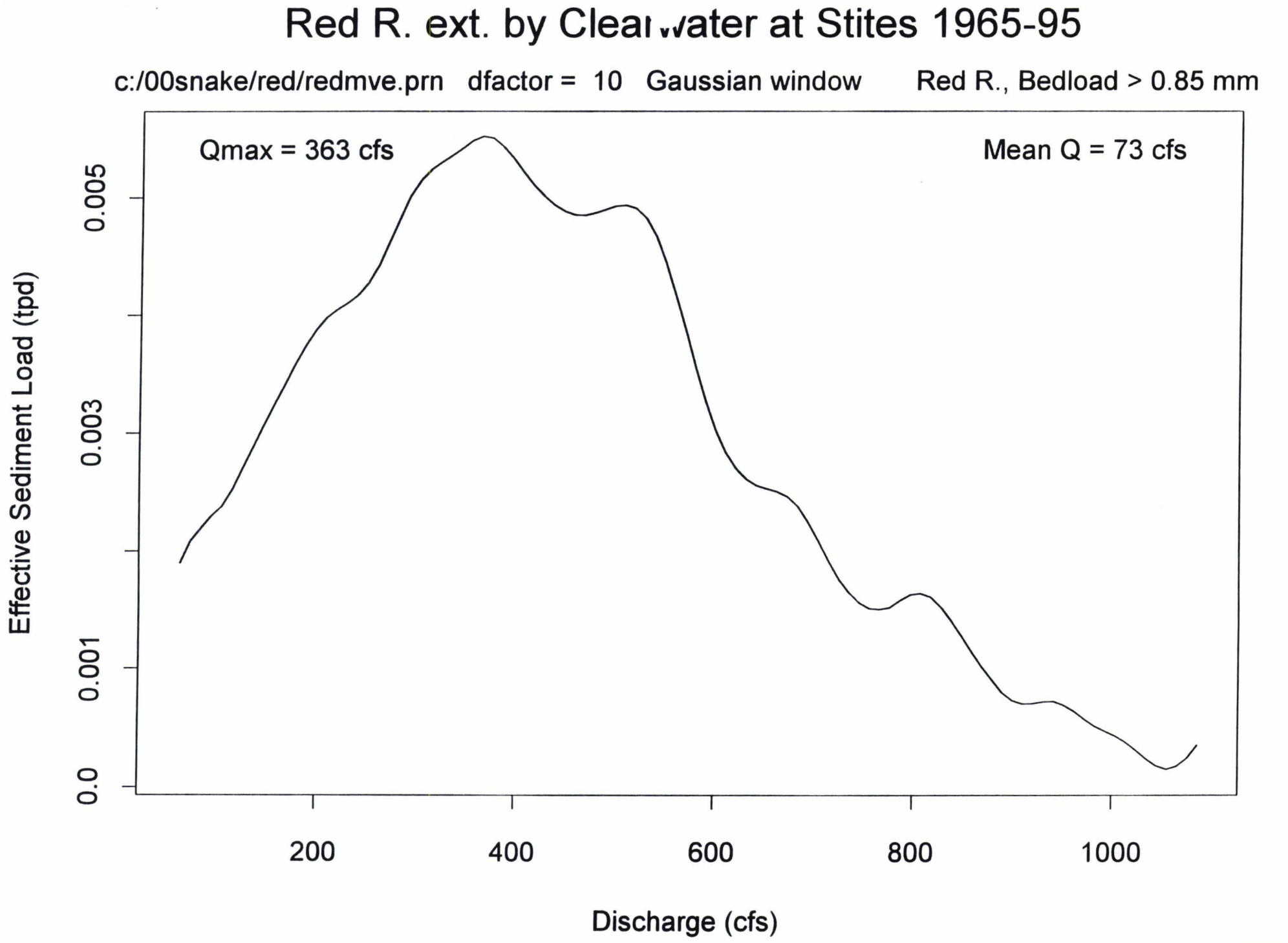
Fri Dec 6 13:41:23 1996

Rapid R. ext. by Salmon at White Bird 1911-17,20-95

C:/00snake/rapid/rapidmve.prn dfactor = 10 Gaussian window Rapid R., Bedload > 0.85 mm

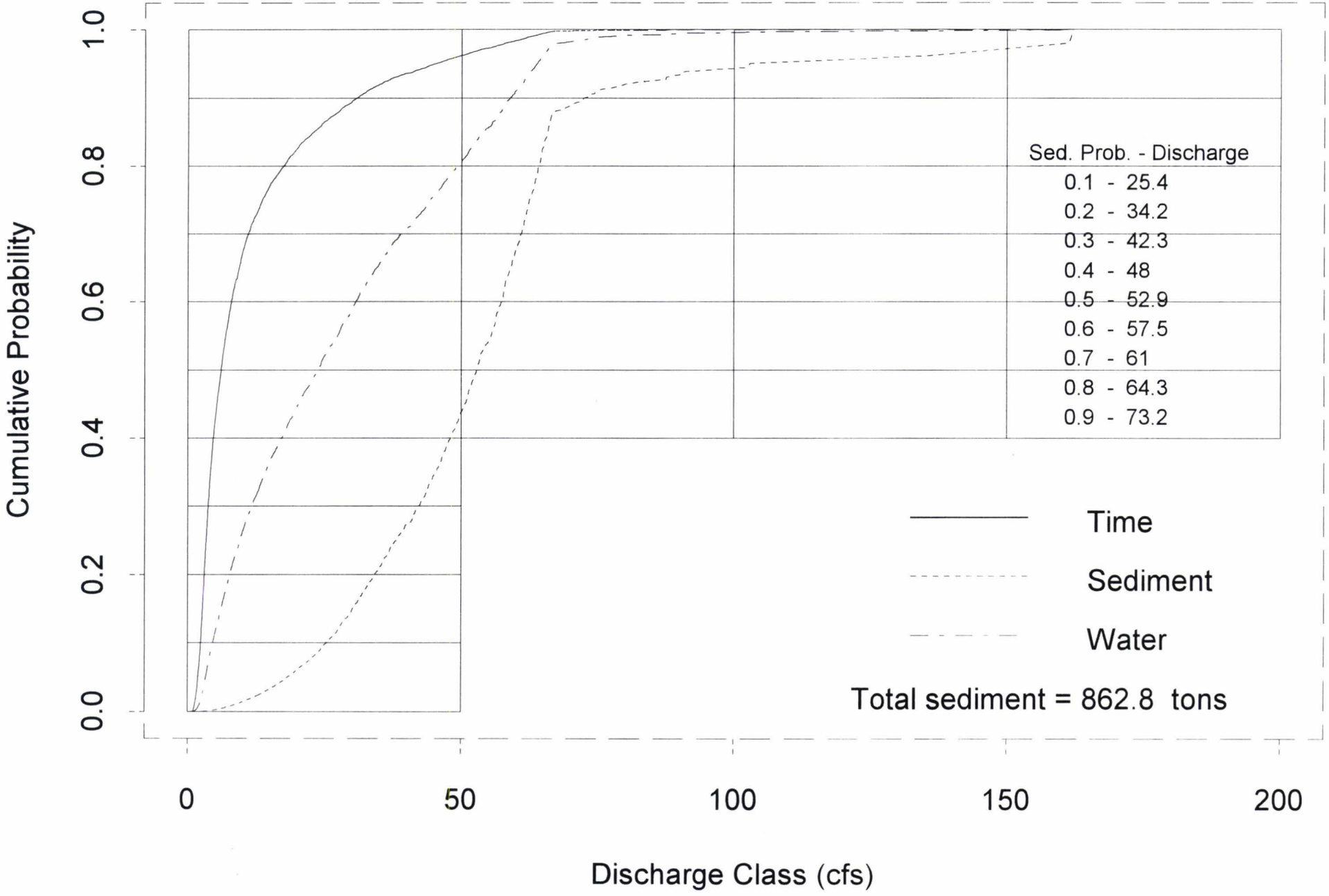


Wed Jan 22 21:56:46 1997


Red R. ext. by Clearwater at Stites 1965-95
c:/00snake/red/redmve.prn dfactor = 10 Gaussian window
Red R., Bedload > 0.85 mm
Qmax = 363 cfs
Mean Q = 73 cfs
Effective Sediment Load (tpd)
0.0
0.001
0.003
0.005
200
400
600
800
1000
Discharge (cfs)
Wed Jan 22 21:58:03 1997

Catspur Ck. ext. by NF Clearwater 1968-95

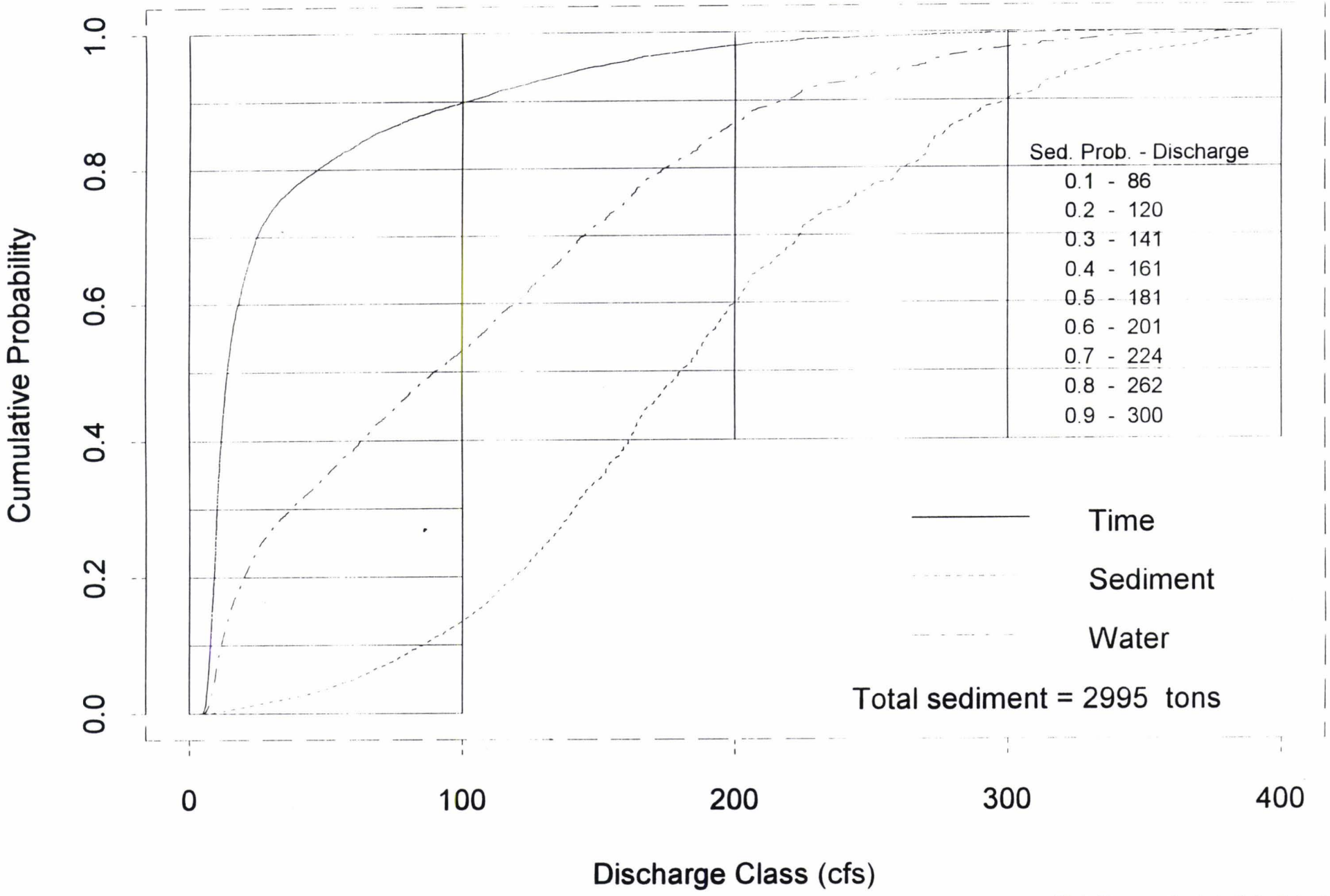
c:/0streams/cats/cats_bd.prn Catspur Ck., Bedload > 0.85 mm



Tue Feb 4 11:18:43 1997

Dollar Cr. ext. by SF Salmon 1967-82,86,90-95

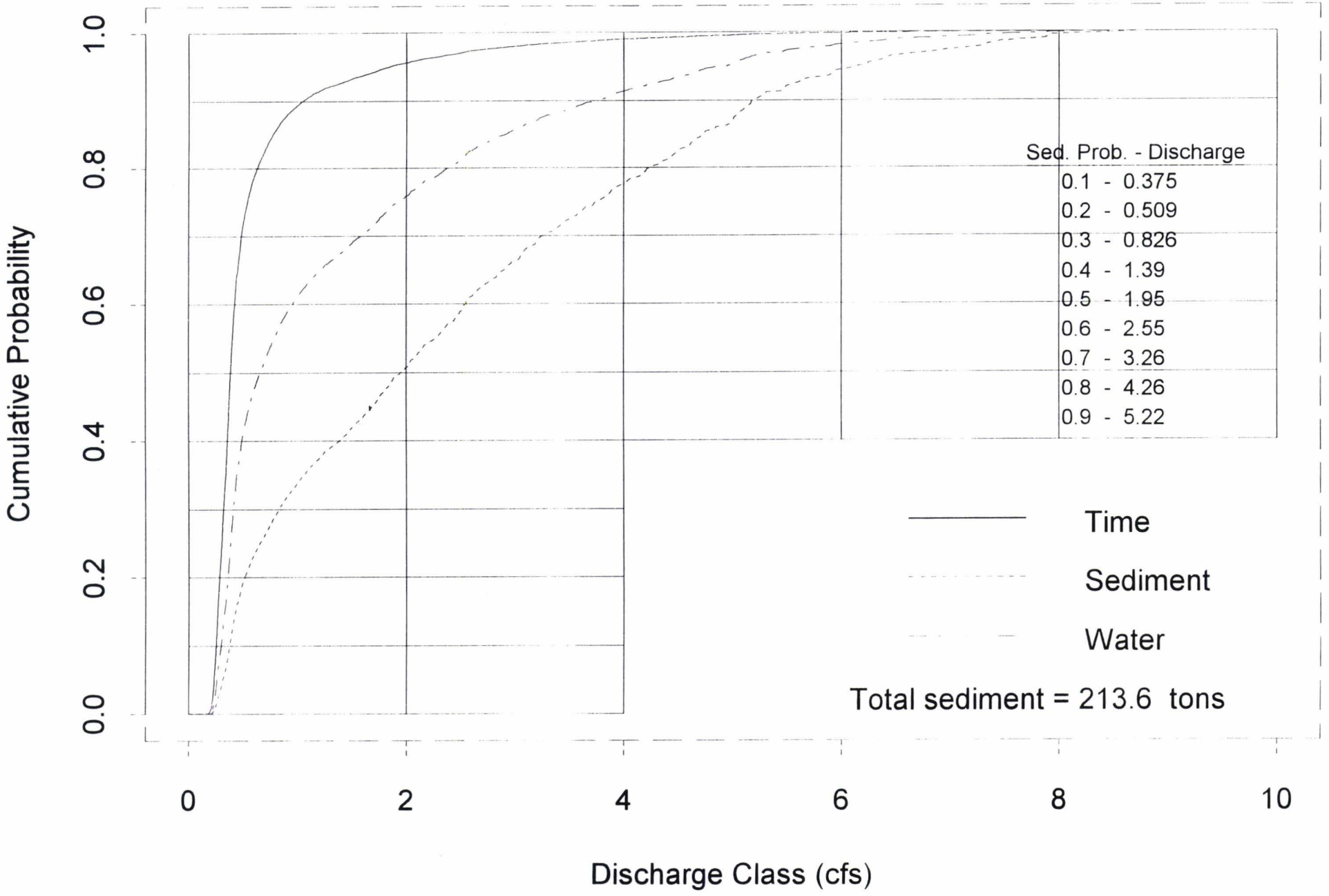
c:/other.str/dollar/doll_bd.prn Dollar Ck., Bedload > 0.85 mm



Fri Dec 6 14:39:01 1996

Eggers Ck. 1966-93

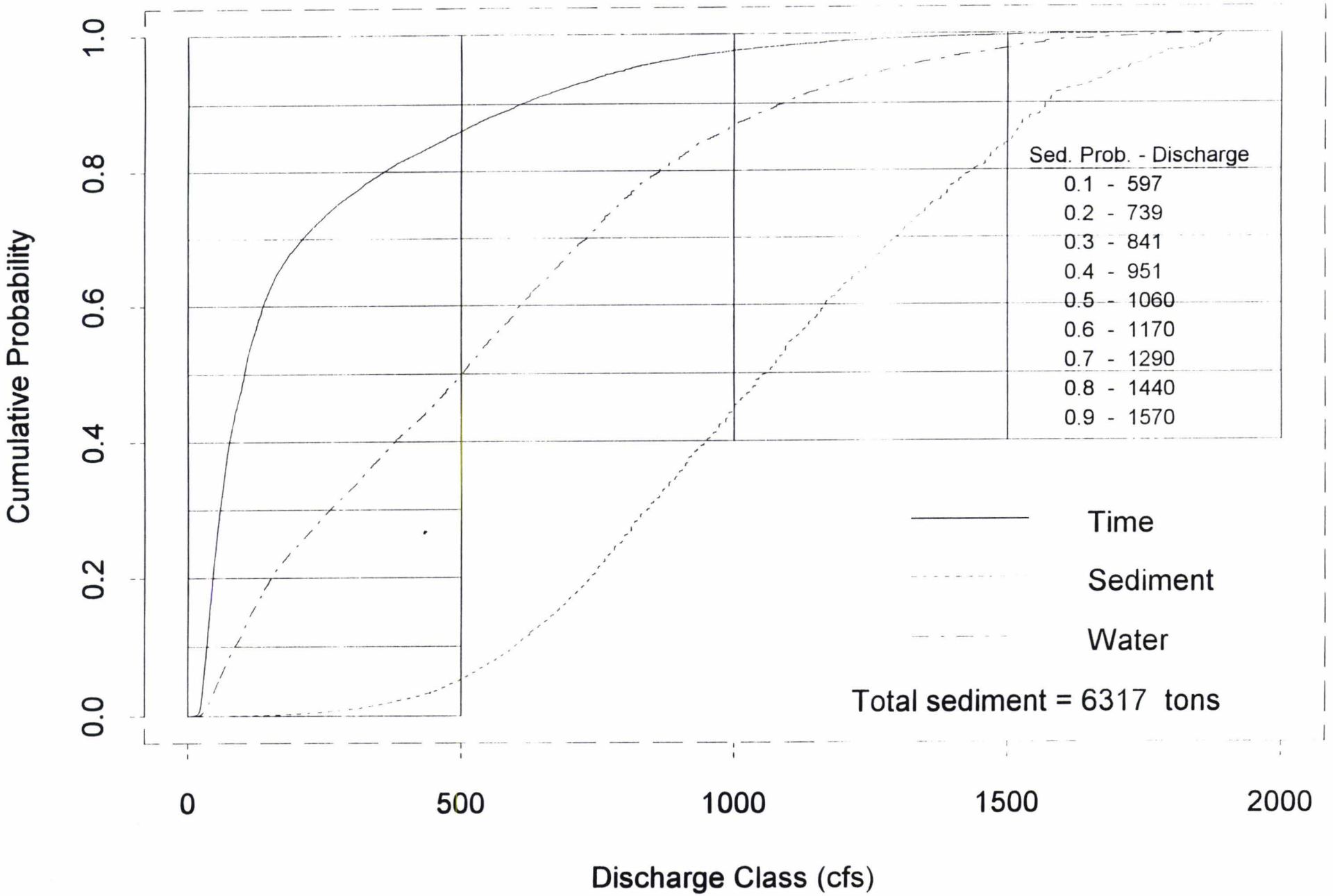
c:/0streams/egger/egger_bd.prn Eggers Ck. Bedload, All sizes



Thu Jan 9 16:30:04 1997

Fish Ck. ext by Lochsa 1911-12,30-95

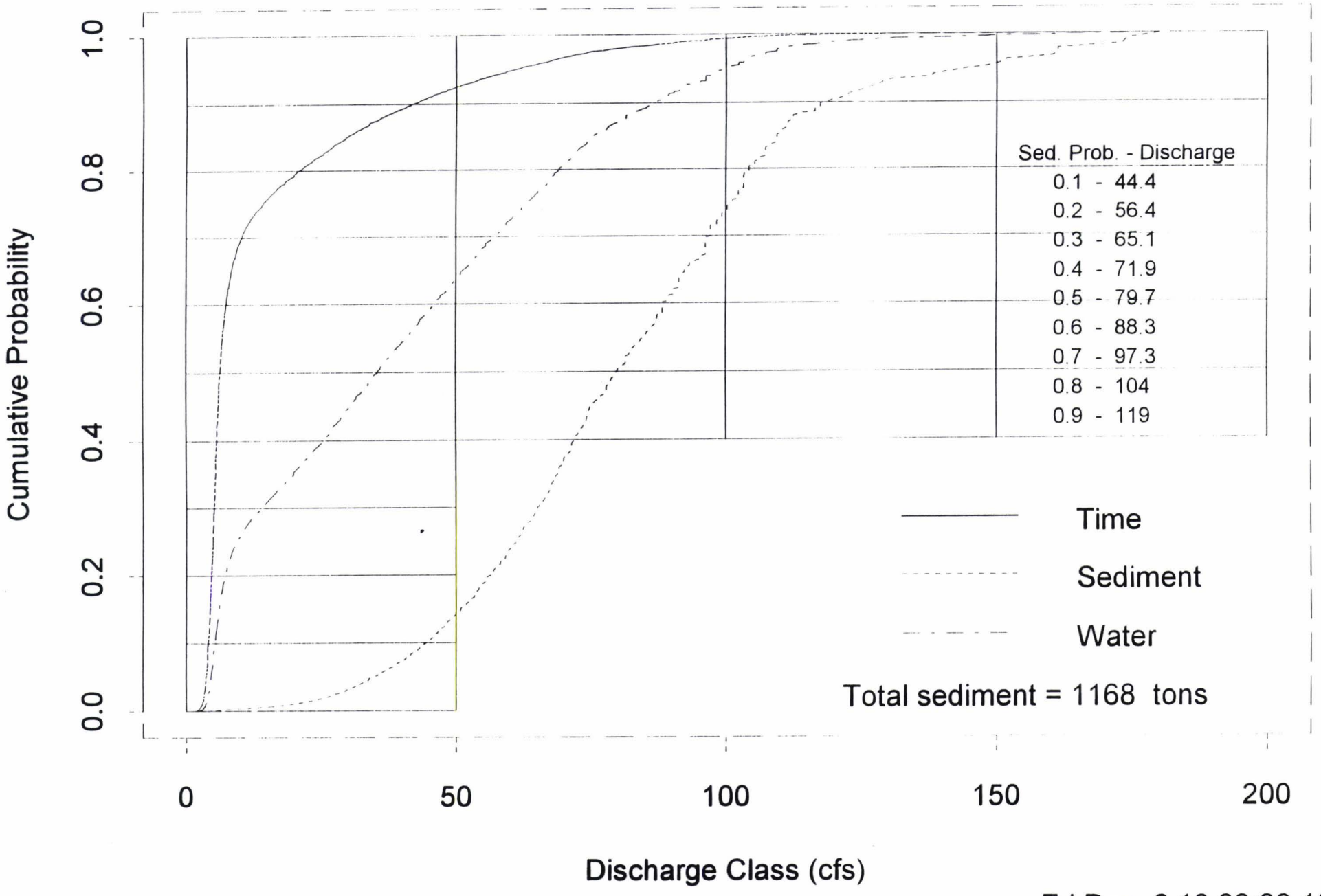
c:/other.str/fish/fish_bd.prn Fish Ck., Bedload > 0.85 mm



Fri Dec 6 15:12:23 1996

4th of July Ck., Ext. by Valley 1912-13,22-71,93-95, ln transform

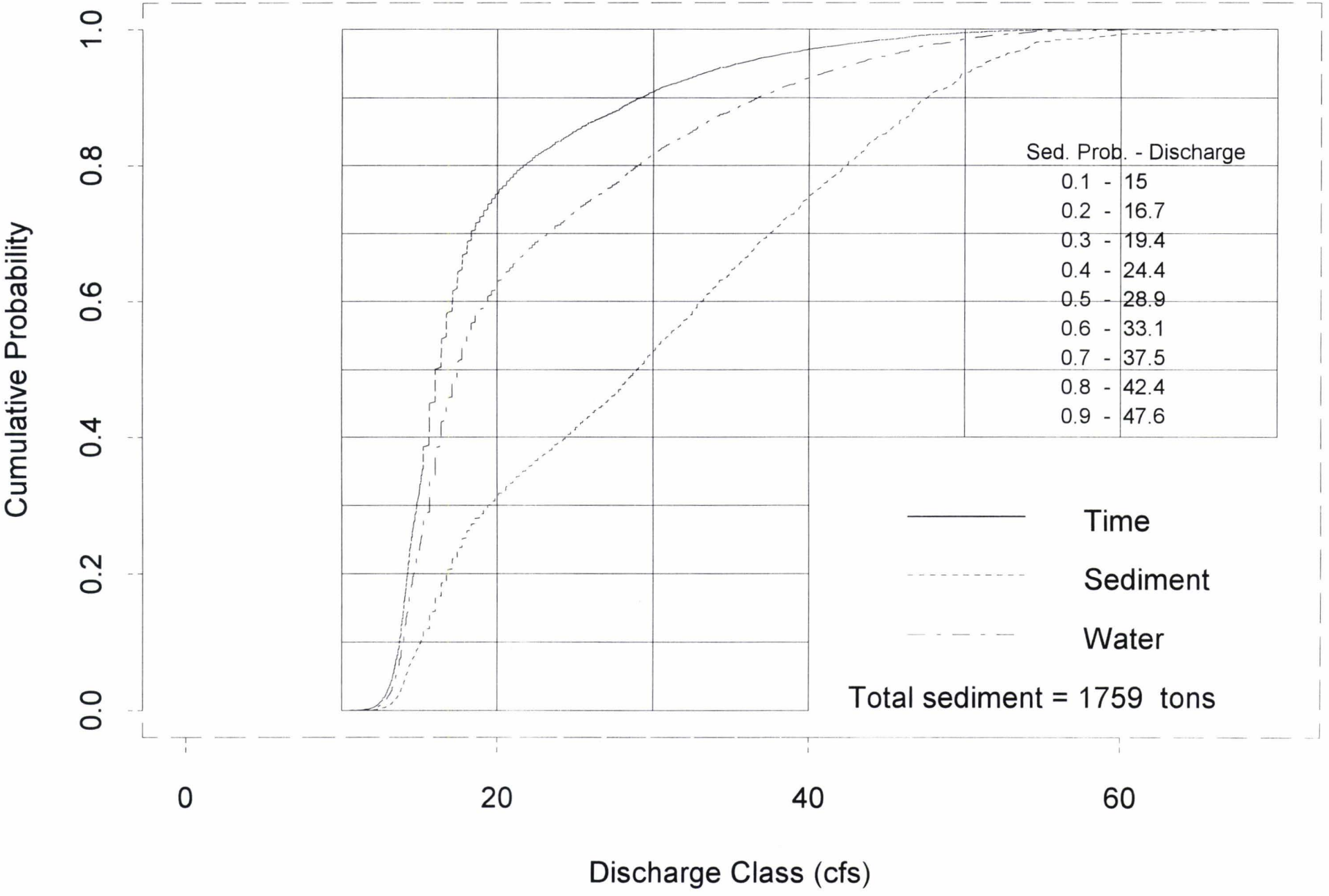
c:/cwrudat/4th/4th_bd.prn 4th of July Ck., Bedload > 0.85 mm



Fri Dec 6 13:33:33 1996

Hawley Ck ext. by Squaw (USGS) 1973-95

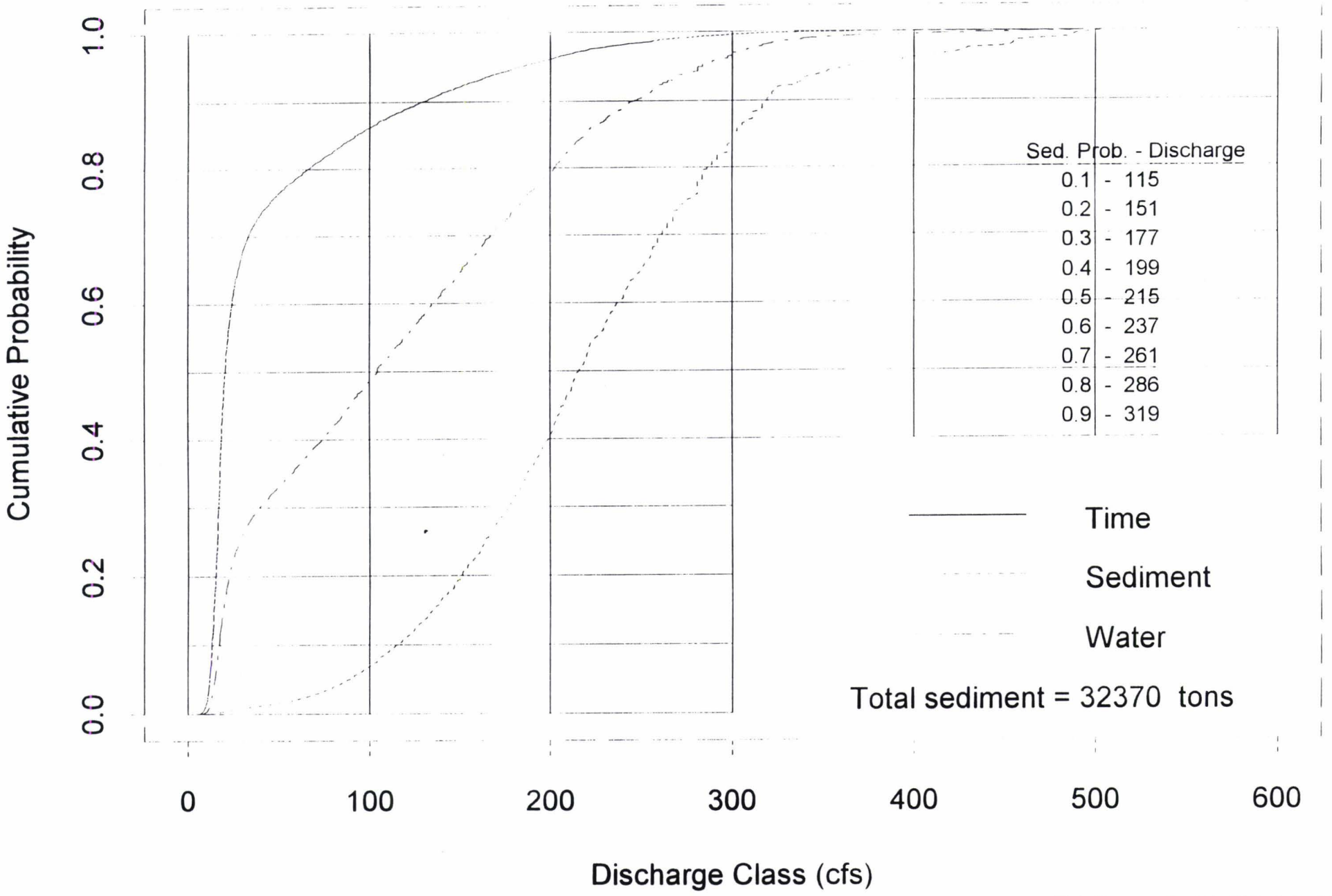
c:/0streams/hawly/hawly_bd.prn Hawley Ck. Bedload > 0.85 mm 1990-94



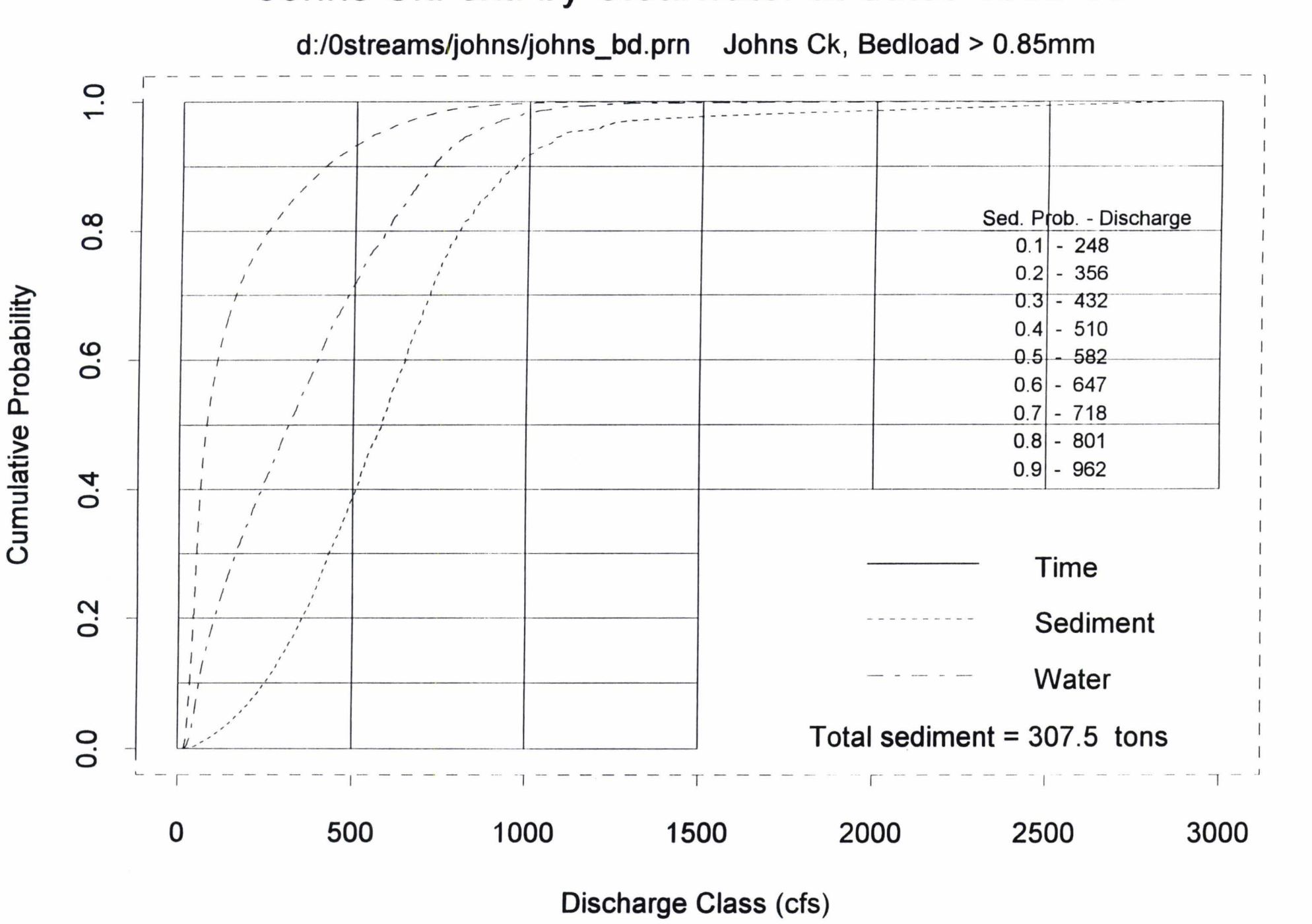
Fri Jan 10 16:02:34 1997

Herd Ck. ext. by Valley 1912-13,22-71,93-95

c:/cwrudat/herd/herd_bd.prn Herd Ck., Bedload > 0.85 mm

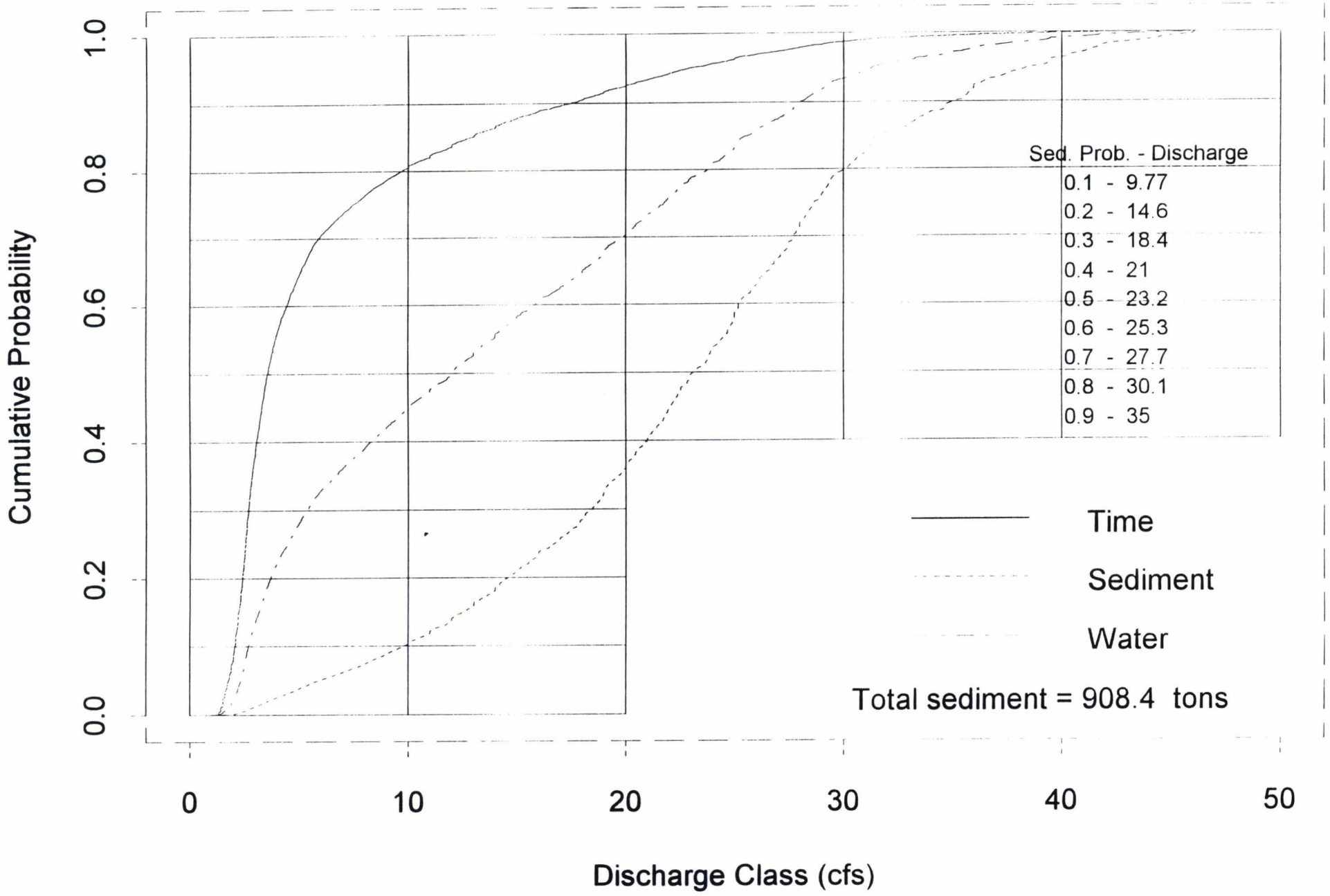


Fri Dec 6 13:37:18 1996


Johns Ck. ext. by Cle..water at Stites 1965-95
d:/0streams/johns/johns_bd.prn Johns Ck, Bedload > 0.85mm
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
500
1000
1500
2000
2500
3000
Discharge Class (cfs)
Sed. Prob. - Discharge
0.1 - 248
0.2 - 356
0.3 - 432
0.4 - 510
0.5 - 582
0.6 - 647
0.7 - 718
0.8 - 801
0.9 - 962
Time
Sediment
Water
Total sediment = 307.5 tons
Wed Jan 22 21:51:19 1997

Little Buckhorn ext. by SF Salmon 1967-82,86,90-95

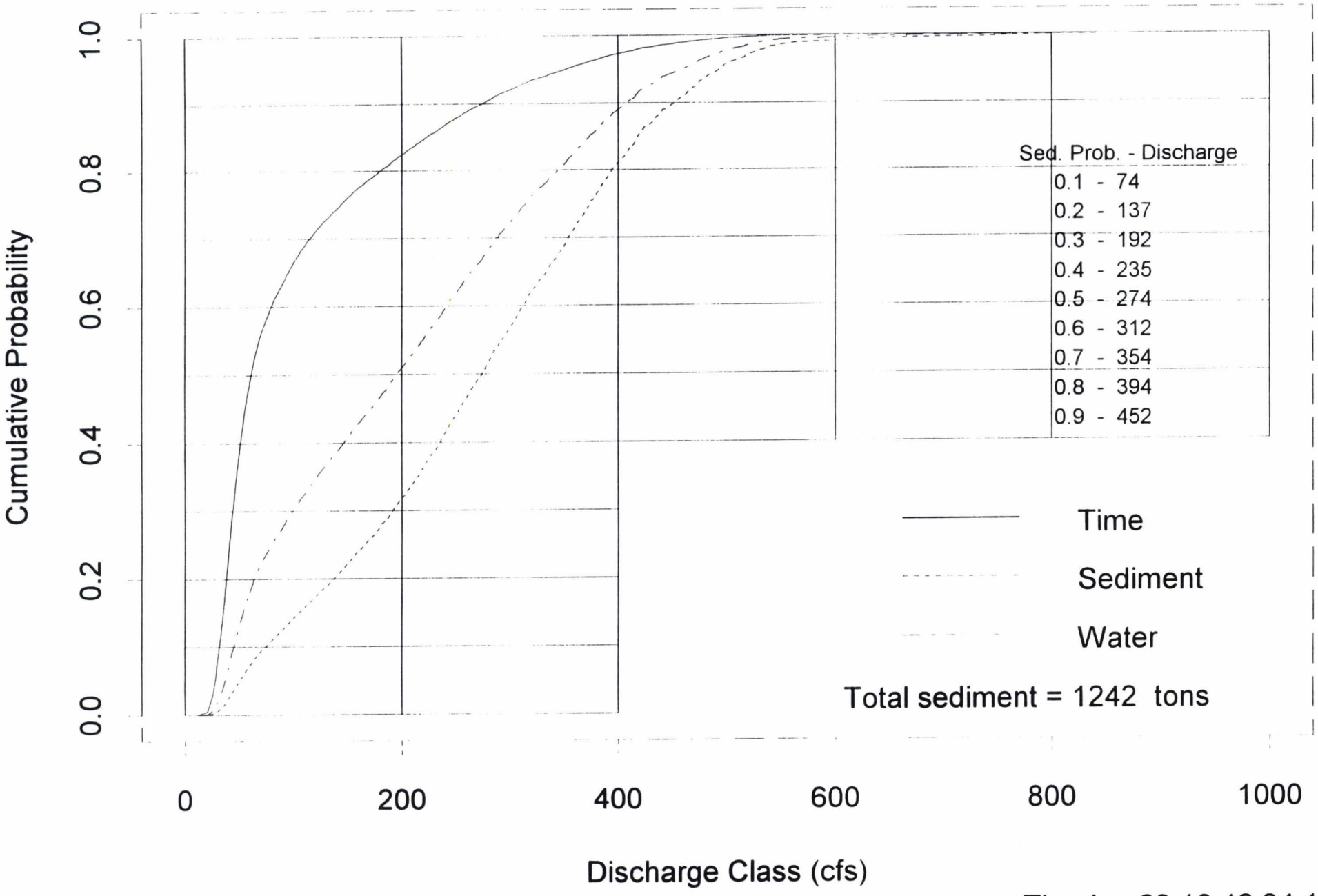
c:/other.str/lbuck/lbuck_bd.prn Little Buckhorn, Bedload > 0.85 mm



Fri Dec 6 15:14:20 1996

Little Slate Creek ext. by Little Salmon 1952-54, 57-95

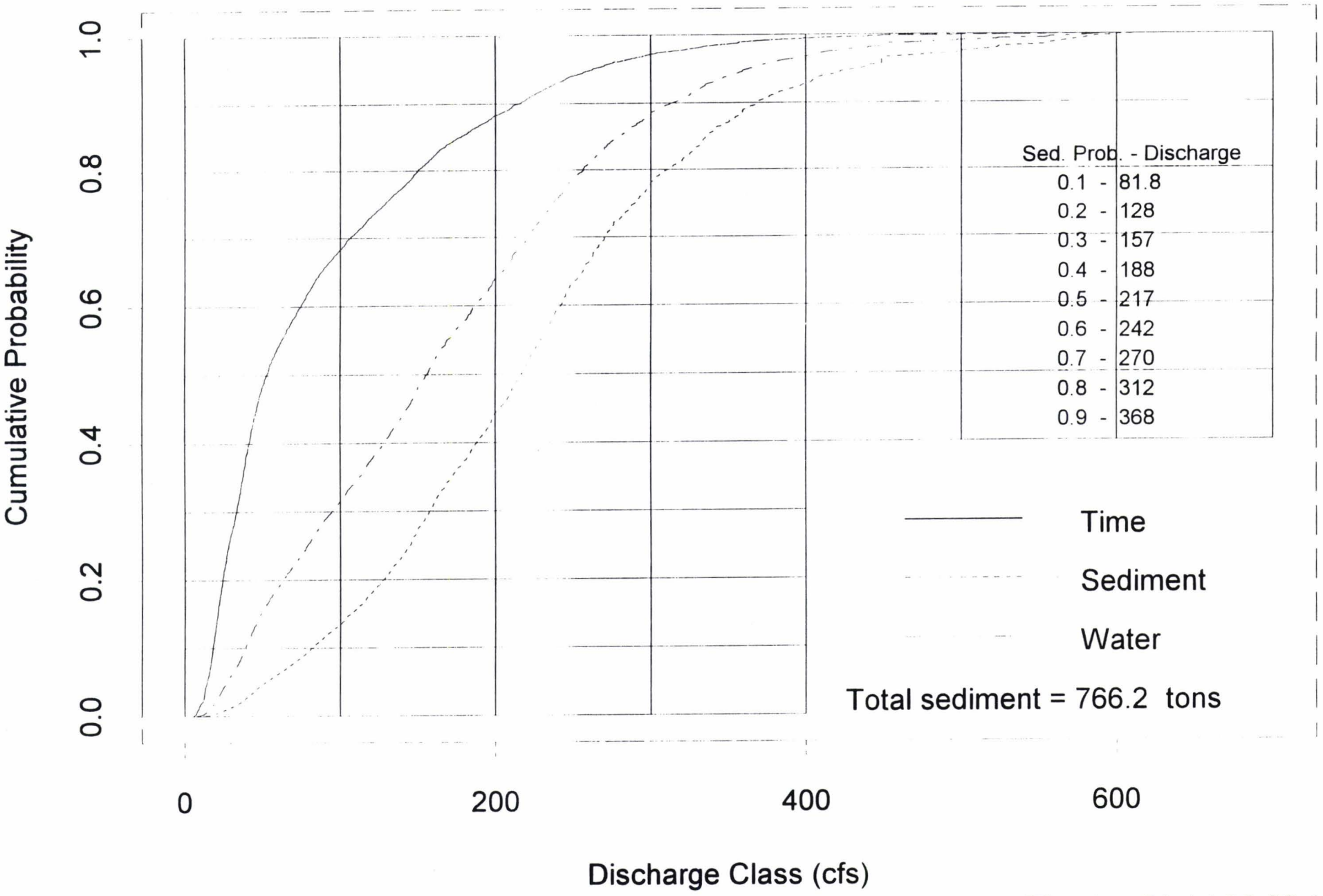
c:/0streams/lsc/lsc_bd.prn Little Slate Ck, Bedload > 0.85 mm



Thu Jan 23 10:46:34 1997

Lolo Ck. ext. by Loio nr. Greer 1980-95

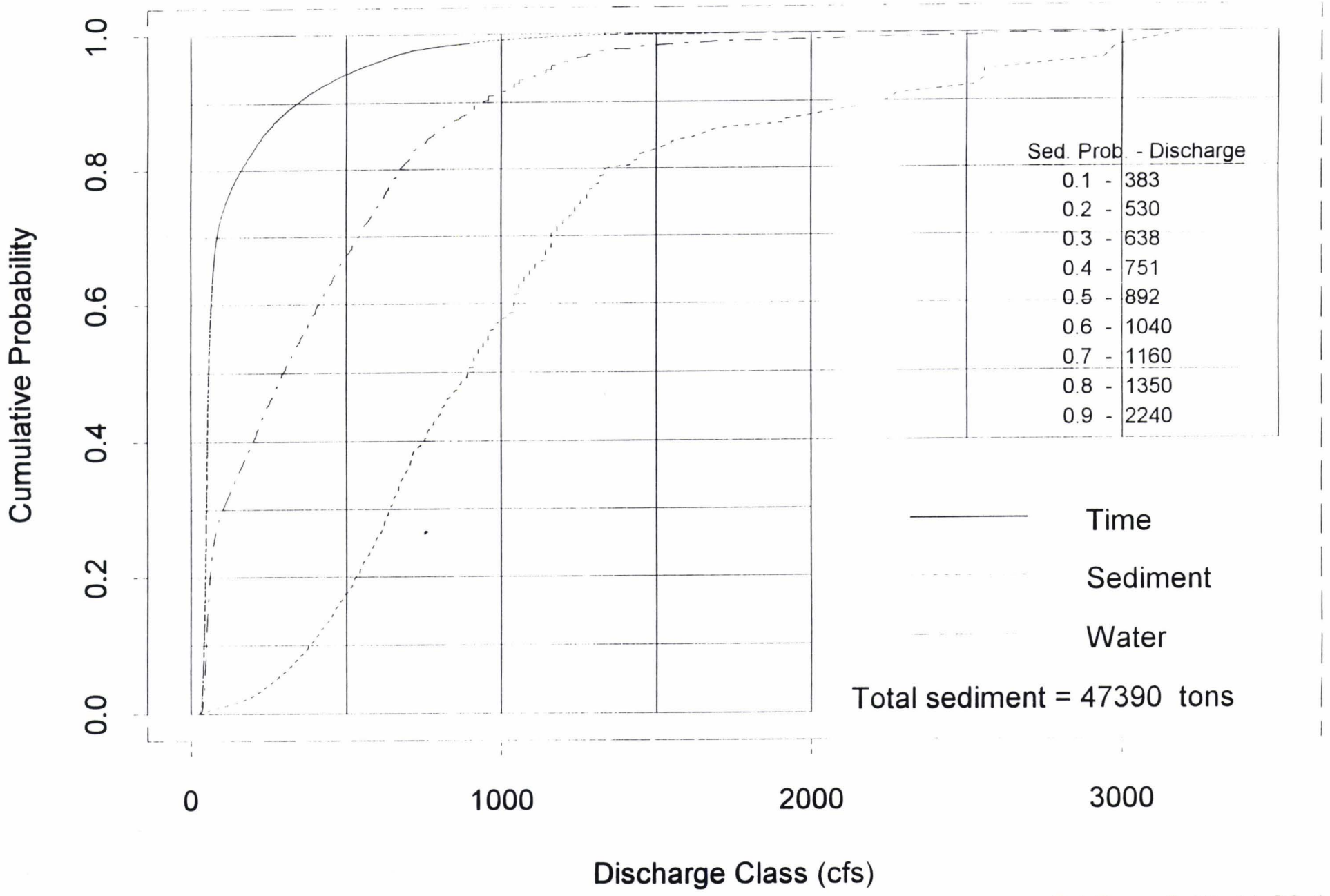
c:/0streams/lolo/lolo_bd.prn Lolo Ck., Bedload > 0.85 mm



Thu Jan 23 14:36:20 1997

Marsh Ck. ext. by Valley 1912-13,22-71,93-95

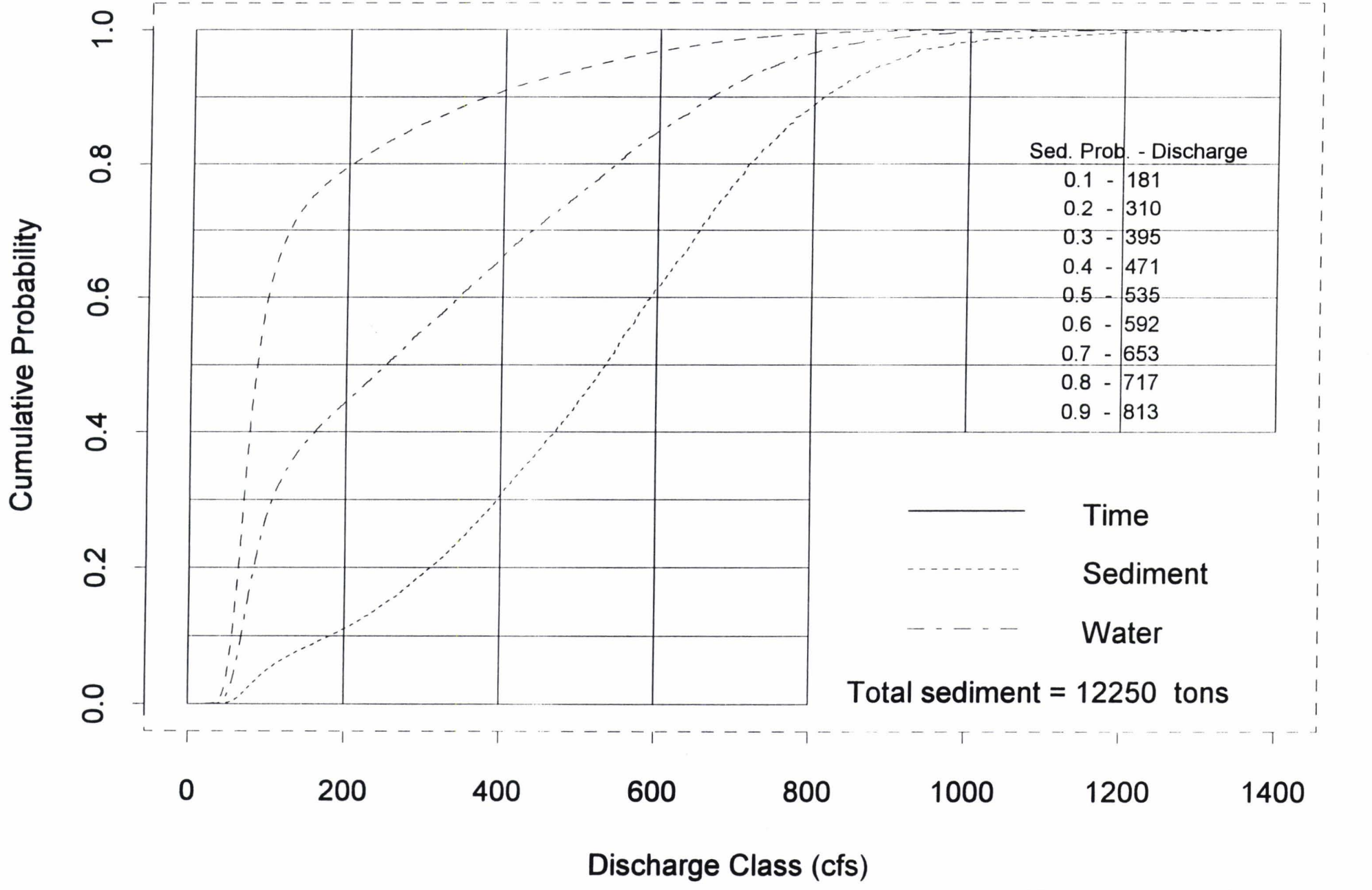
c:/cwrudat/marsh/marsh_bd.prn Marsh Ck., Bedload > 0.85 mm



Fri Dec 6 13:41:39 1996

Rapid R. ext. by Salmon at White Bird 1911-17,20-95

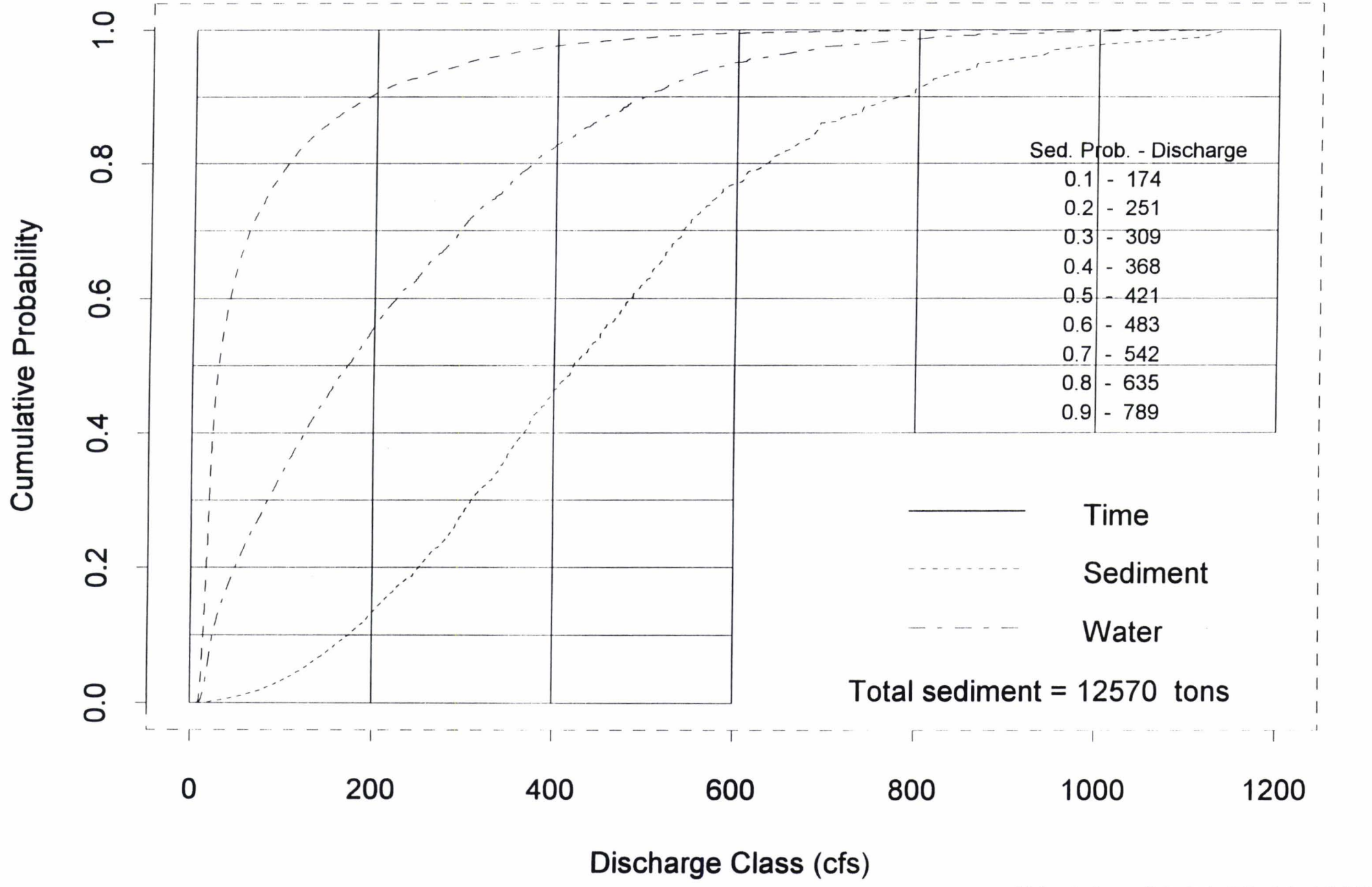
d:/0streams/rapid/rapid_bd.prn Rapid R., Bedload > 0.85 mm



Wed Jan 22 21:56:54 1997

Red R. ext. by Clear Water at Stites 1965-95

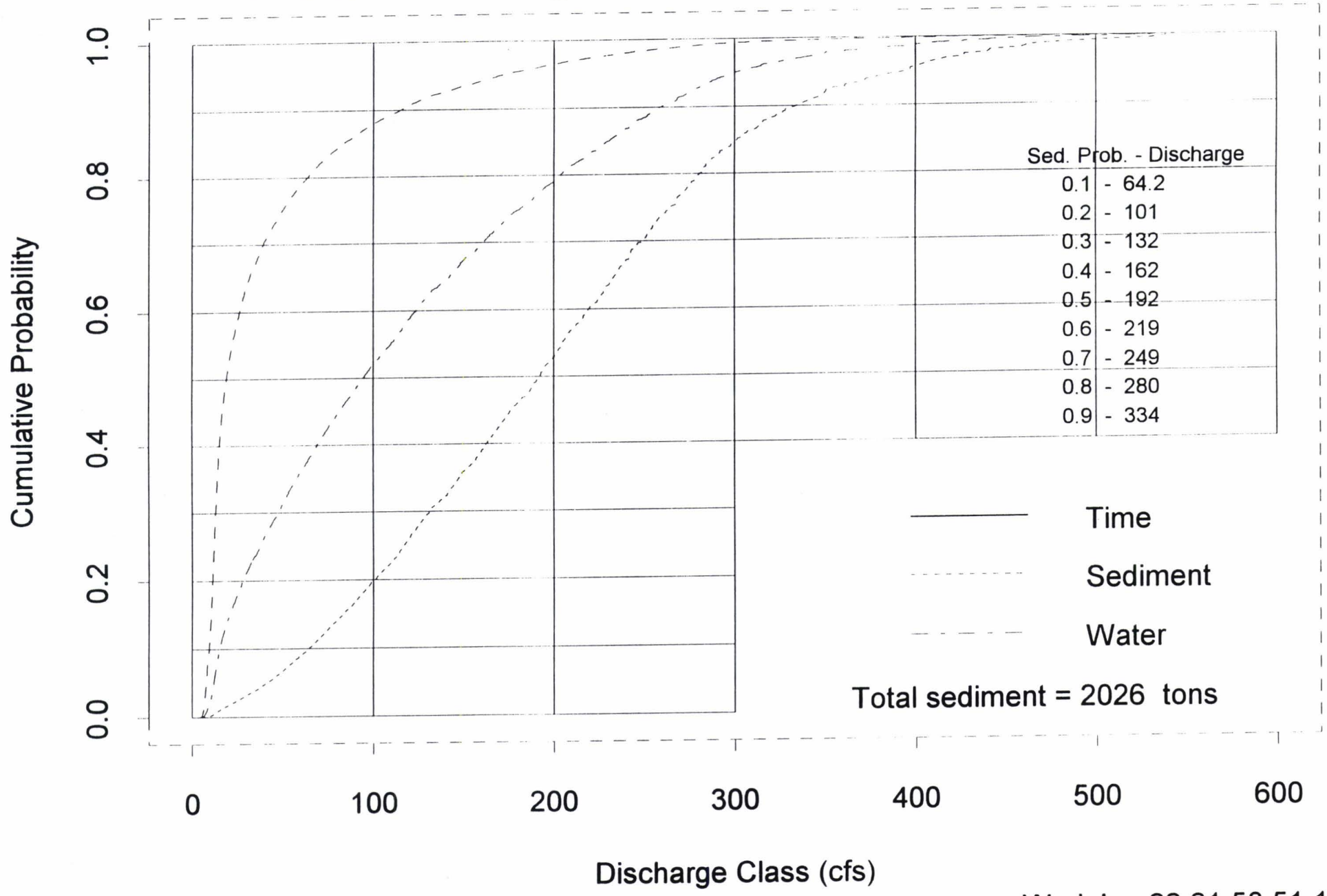
D:/0streams/red/red_bd.prn Red R., Bedload > 0.85 mm



Wed Jan 22 21:58:11 1997

SF Red R. ext. by Clearwater at Stites 1965-95

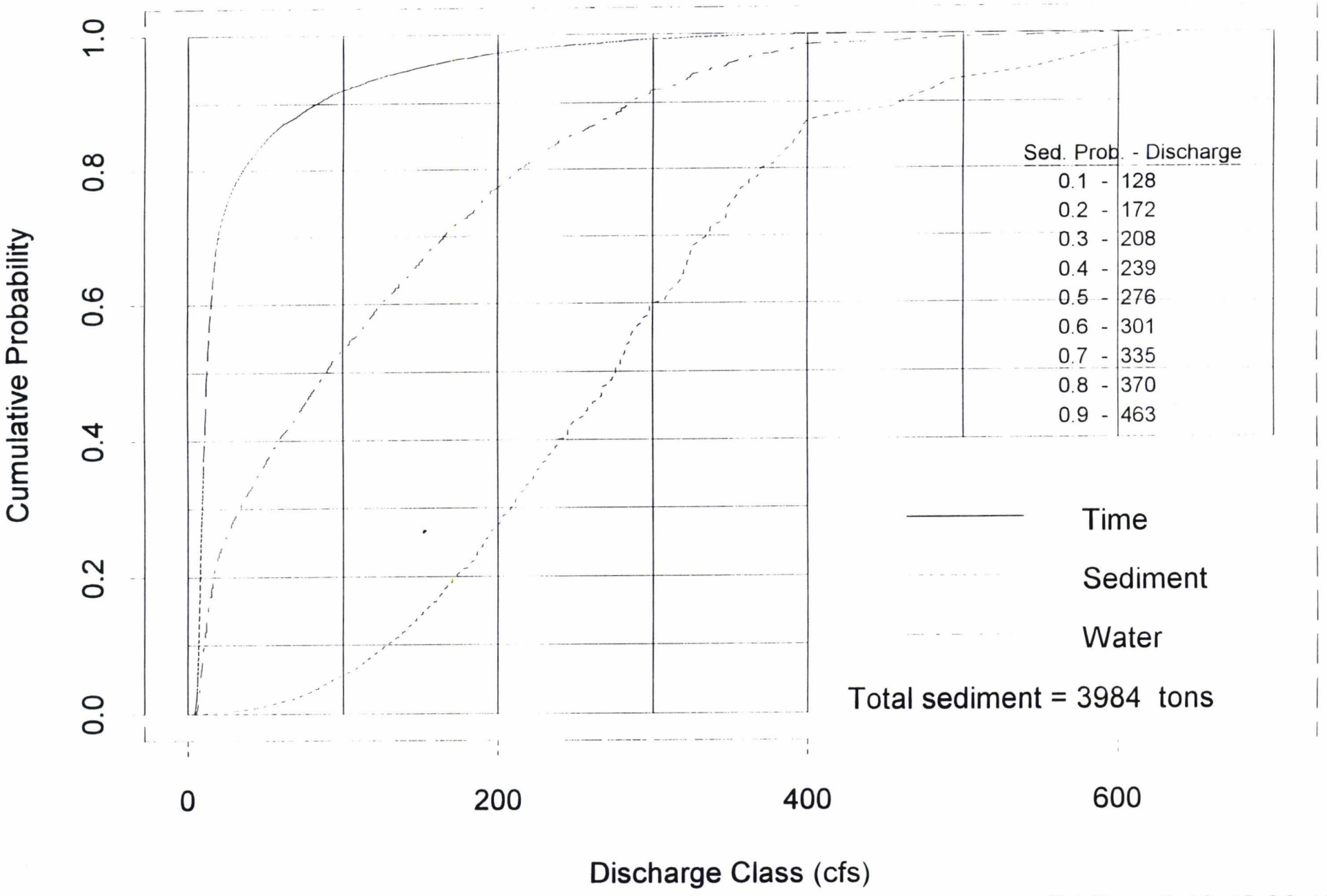
d:/0streams/sfred/sfred_bd.prn South Fork Red R., Bedload > 0.85 mm



Wed Jan 22 21:58:51 1997

Squaw Creek 1973-95

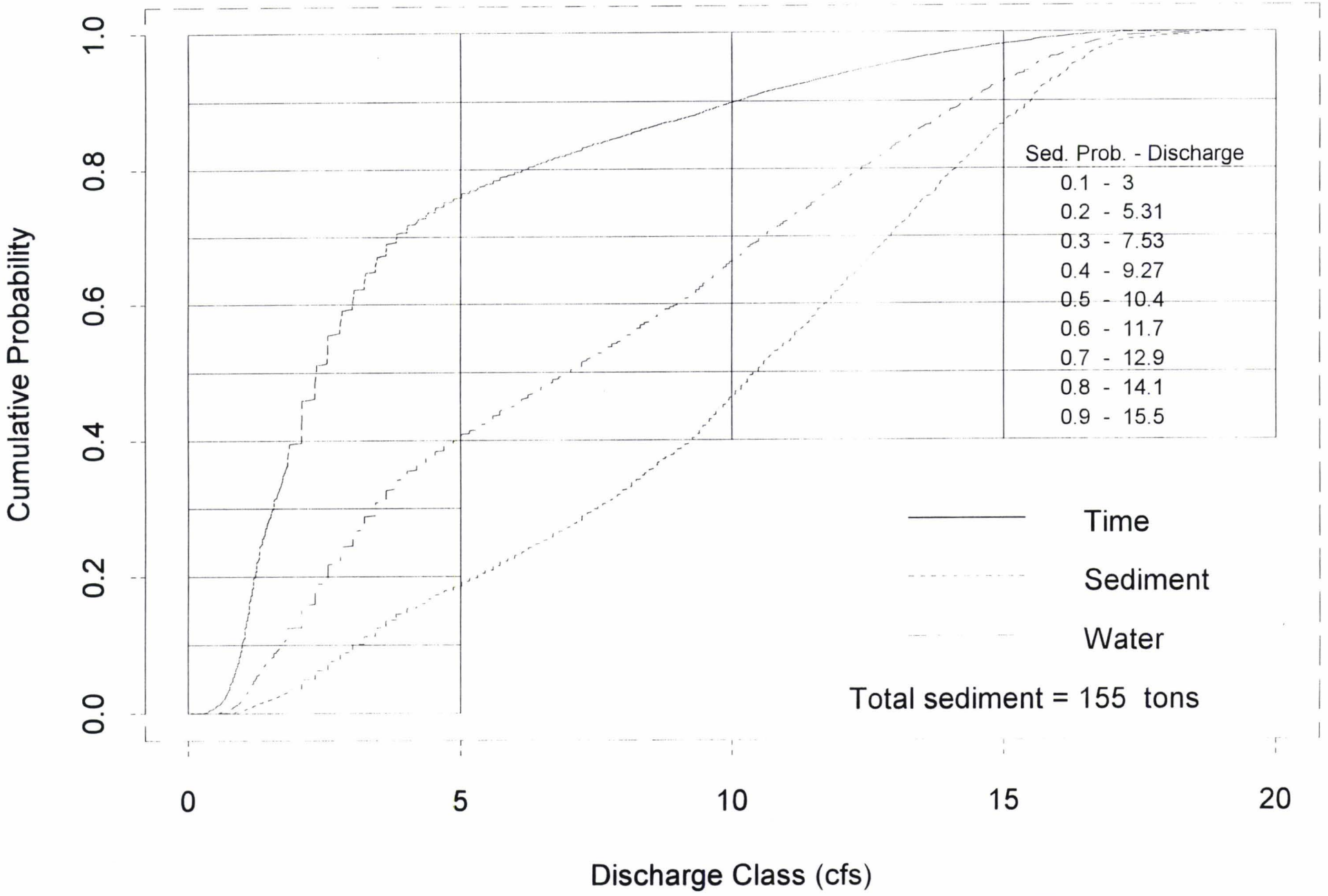
c:/cwrudat/squaw/squaw_bd.prn Squaw Creek, Bedload > 0.85 mm



Fri Dec 6 13:43:30 1996

Squaw Ck (USFS) ext. by Squaw (USGS) 1973-95

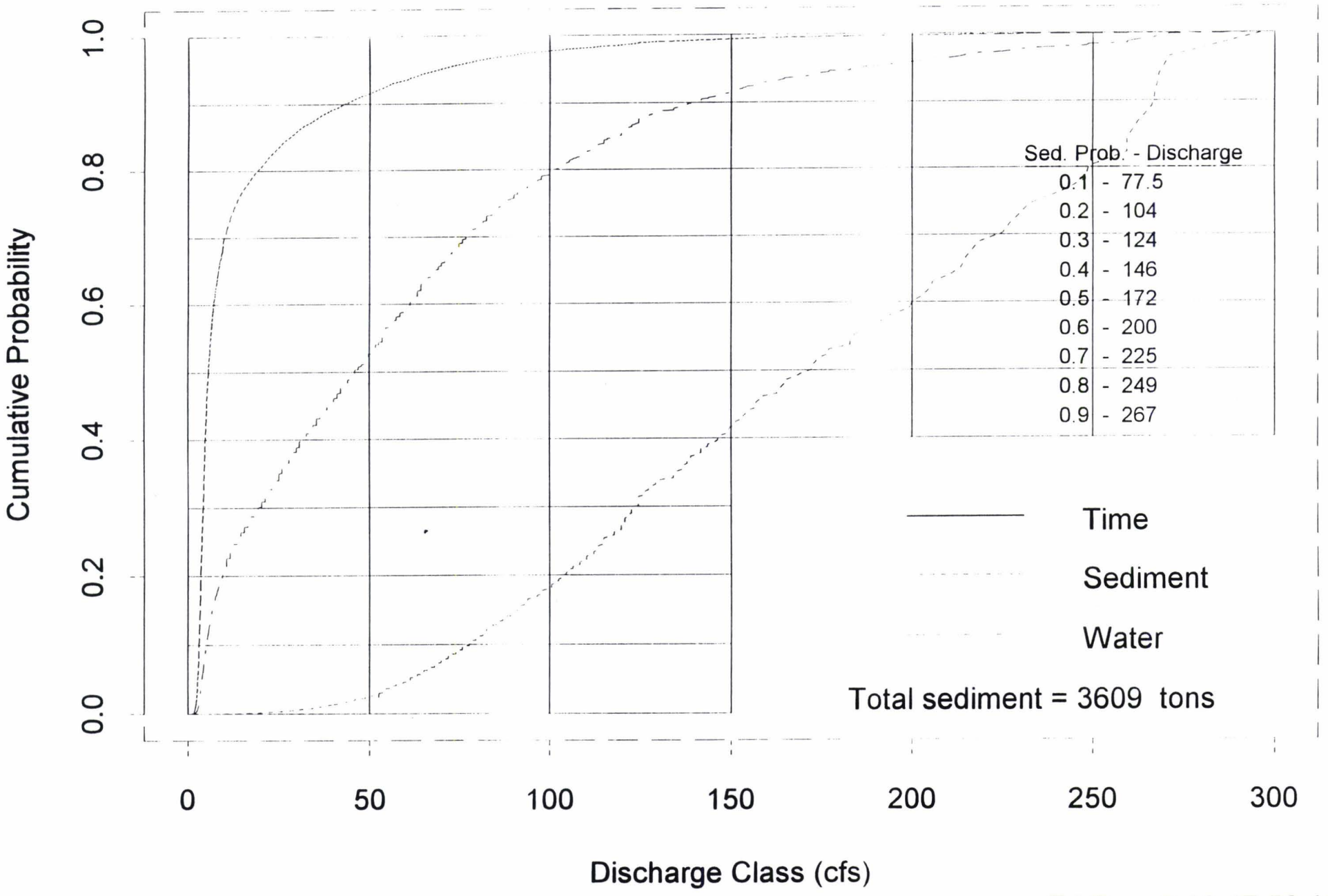
c:/0streams/sqwfs/sqwfs_bd.prn Squaw Ck (USFS) Bedload > 0.85 mm



Thu Jan 9 15:56:03 1997

Thompson Ck. 1973-95

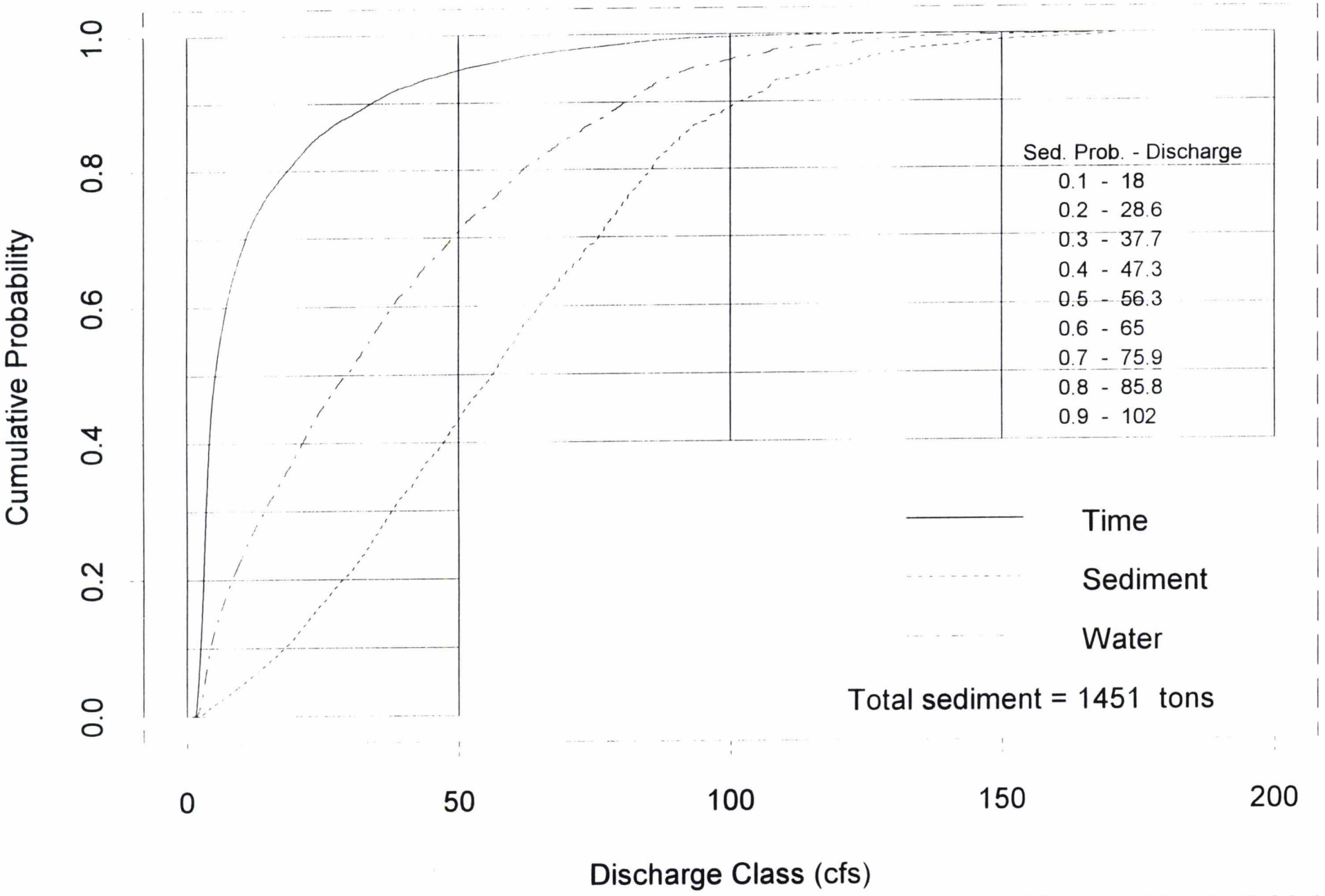
c:/cwrudat/thompson/thomp_bd.prn Thompson Ck., Bedload > 0.85 mm



Fri Dec 6 13:47:56 1996

Trapper Ck. ext. by Clearwater at Stites 1965-95

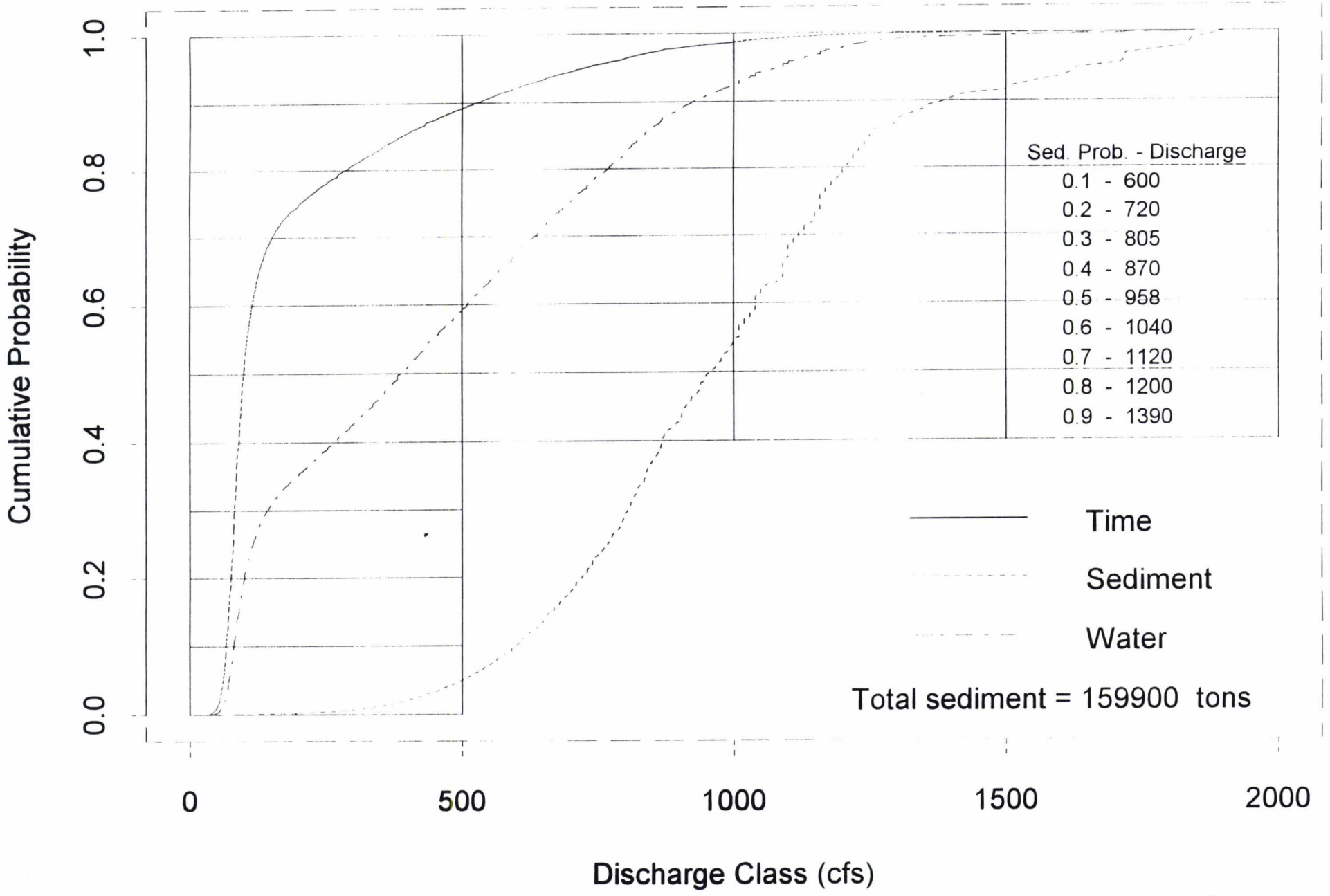
c:/0streams/trap/trap_bd.prn Trapper Ck., Bedload > 0.85 mm



Thu Jan 23 10:50:06 1997

Valley Creek 1912-13,22-71,93-95

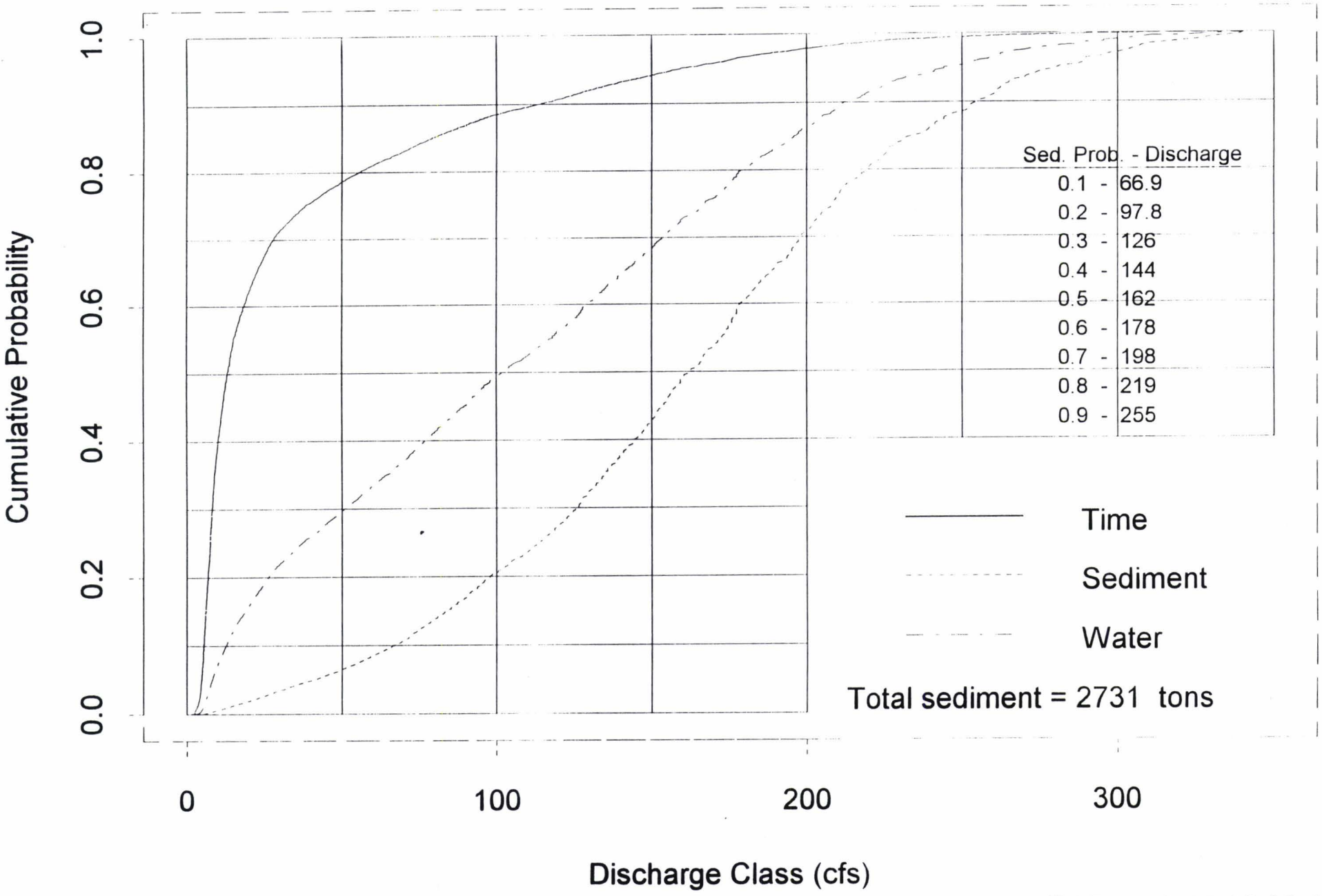
c:/cwrudat/valley/valle_bd.prn Valley Ck., Bedload > 0.85 mm



Fri Dec 6 13:50:47 1996

WF Buckhorn ext. by SF Salmon 1967-82,86,90-95

c:/other.str/wfbuck/wfbuc_bd.prn WF Buckhorn Bedload > 0.85 mm



Fri Dec 6 15:15:39 1996